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**SCIENCE OF
INTERSTELLAR**

Kip Thorne on the sci-fi blockbuster

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- How humanity will be affected
- Who will find out first

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Welcome to issue 58!



It's the question on everyone's lips: what would happen if we actually made contact with intelligent alien life? This issue of **All About Space** has the answer, as we catch up with the likes of SETI astronomer Seth Shostak, who reveals Earth's action plan if we ever do detect a signal, who will be the very first person to know, and how such a discovery will affect you. Turn to page 16 for all the details.

Also this month, we look into the future and at the ultimate fate of the universe. According to recent research, we could very well be heading for a Big Rip - where the cosmos expands faster and faster, eventually tearing itself and everything in it apart. Current models suggest that our Solar System would last for a mere three months after dark energy makes the

cosmos expand at an alarming rate.

If, like me, you're constantly in awe of the shots of our universe, taken by ground- and space-based telescopes, you'll love our pick of the most groundbreaking images, which have led the way to the most incredible discoveries of all time. Turn to page 56 to see if your favourite made the list.

If you've always wondered how space-time really works, then wonder no more - we've put together your very own cheat sheet to the fabric of the universe. From what causes gravitational waves to why we age slower during space travel - it's all right in there.

Our final issue of the year goes on sale on 8 December - see you then!

Gemma Lavender
Editor

Contributors

Jonathan O'Callaghan



What would happen if we made alien contact? Jonathan discovers who will be the first to know and how humanity will be affected.

Giles Sparrow



Recent research suggests our universe is heading for an almighty Big Rip. Turn to page 32 for Giles' full account of why it's the likely end to the cosmos.

Colin Stuart



Get clued up on space-time with Colin's cheat sheet to the fabric of the universe. From gravitational waves to time dilation, it's all in there!

Kulvinder Singh Chadha



Browse our gallery of the greatest space images of all time, with Kulvinder's top pick. Did your favourite make the list? Let us know!

Kip Thorne discusses why the sci-fi film *Interstellar* may not be too far from reality

"We are likely to have a reliable understanding of the laws of quantum gravity within the next 30 years"

Kip Thorne, theoretical physicist and scientific advisor for 2014 film *Interstellar* [page 25]

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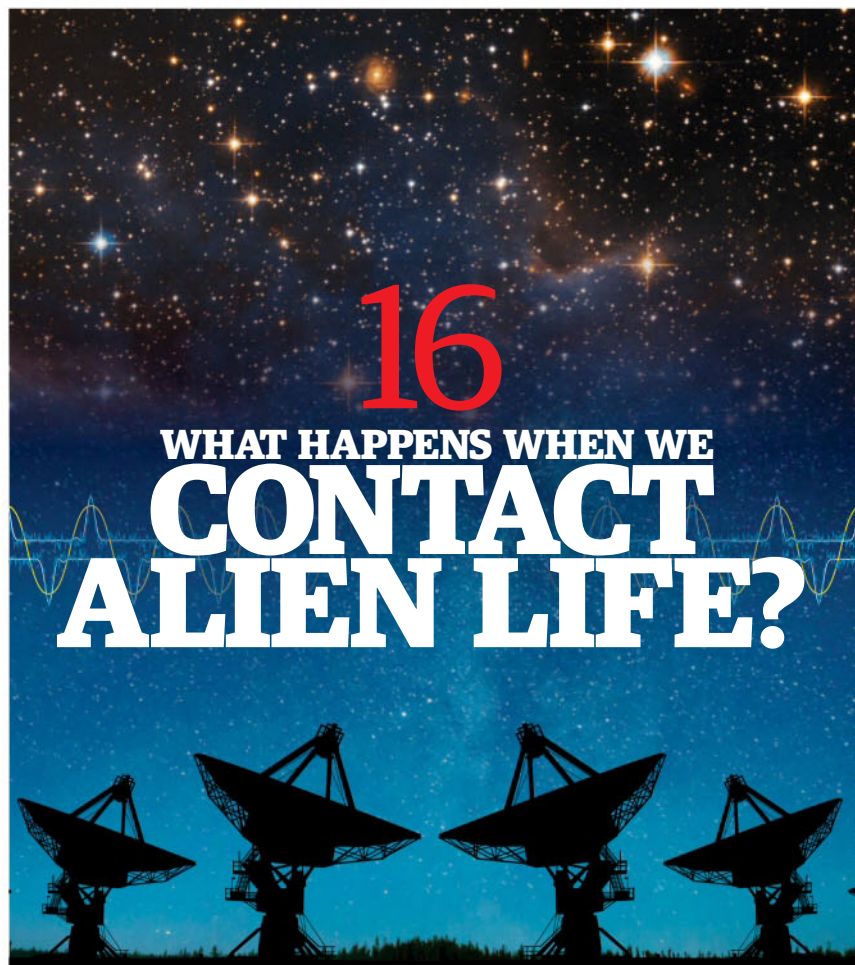
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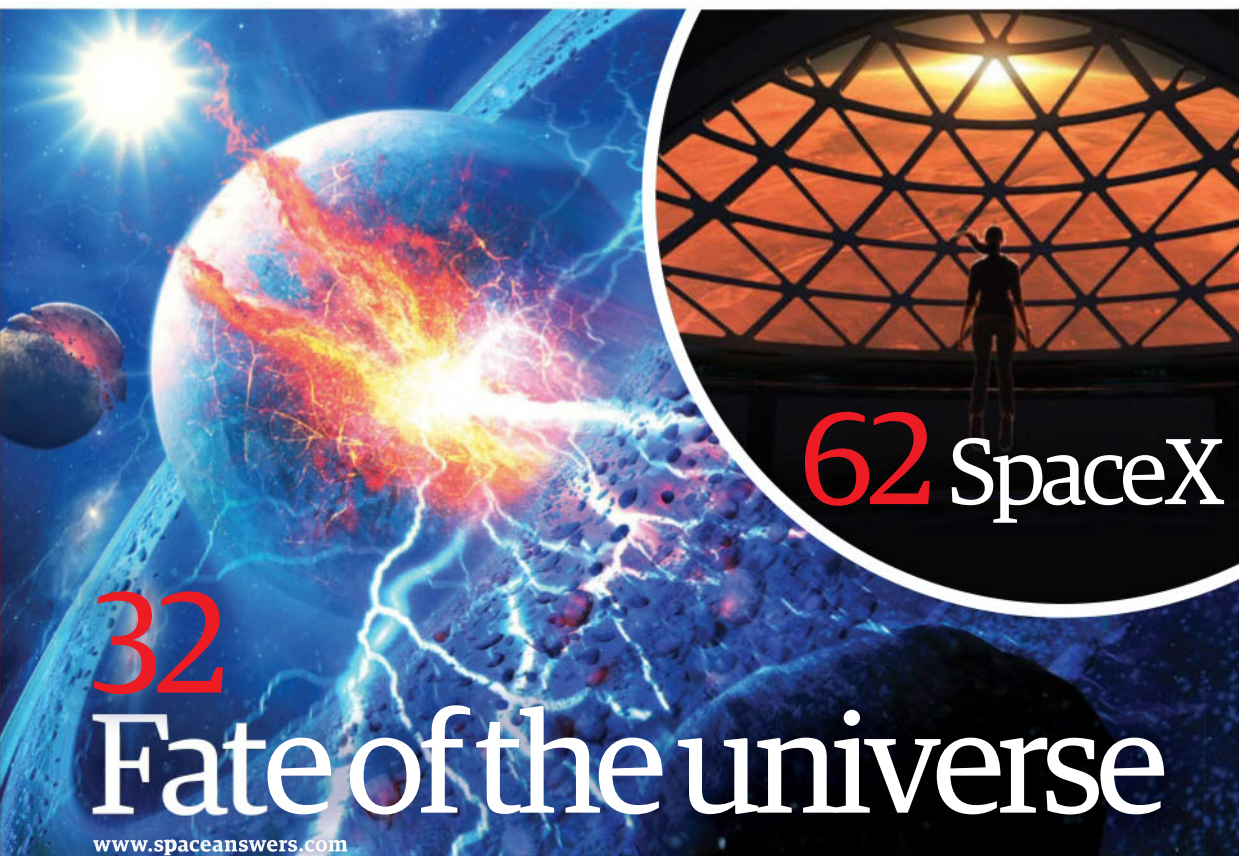
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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

Inspecting an expandable space habitat on the ISS

Astronaut Kate Rubins stops to smile for the camera as she carries out a routine check of the Bigelow Aerospace Expandable Activity Module (BEAM), which was attached to the International Space Station (ISS) in early September (inset). These inflatable partitions are designed to take up less room on a spacecraft while providing a greater volume for living and working in space when expanded.

In the first checkup of BEAM since its installation in May, Rubins thoroughly inspected the habitat by collecting radiation monitors and sampling surfaces inside the habitat to assess the microbe environment. After confirming that the module was indeed in good condition, the astronaut opened up and entered the activity module to install equipment to measure the loads and vibrations, as part of stability checks that take place every three months.







The demise of a Sun-like star

The colourful last hurrah of a star like our Sun was witnessed by NASA's Hubble Space Telescope, as the star ended its life by casting off its outer layers of gas. A burned-out white dwarf can be seen at its centre, sizzling at 200,000 degrees Celsius (360,000 degrees Fahrenheit), while ultraviolet light emitted in the star's death throes makes the nearby material glow.

NGC 2440 is a planetary nebula and serves as a glimpse into the future of our Sun, which will burn out in 5 billion years. Planetary nebulae are common in the Milky Way and, while their name suggests otherwise, these stellar relics are nothing to do with planets; 18th and 19th century astronomers named them, as they resemble the discs of Uranus and Neptune through telescopes.



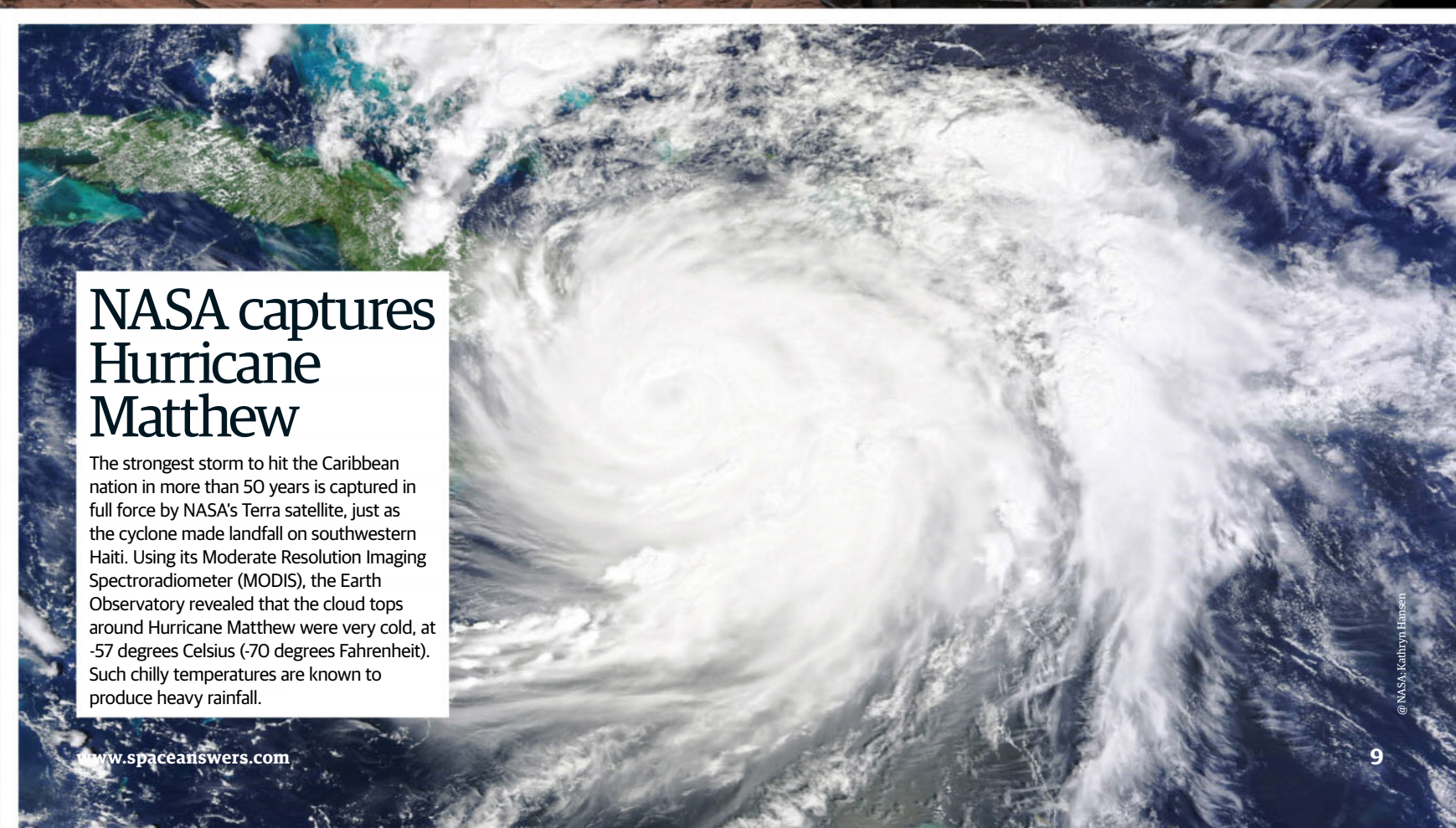
@ NASA; ESA; K. Noll (STScI)



Curiosity's scenic snapshot of Mars

While in an area known as Murray Buttes on lower Mount Sharp, NASA's Curiosity Mars rover took the opportunity to take a panorama using its Mast Camera (Mastcam) of one of the most scenic landscapes it has ever visited. Taken during the rover's 1,451st Martian day of its mission, the view stitches together several individual shots taken by Mastcam's left-eye camera. Dark, flat-topped landforms - also known as mesa - near the centre of the scene rise to around 12 metres (39 feet) above the surrounding plain. The foreground, where it is relatively flat, is part of a geological layer called the Murray formation and it is packed with lakebed deposits. The buttes and mesas rising above the surface are eroded remnants of ancient sandstone, thought to have originated when Martian winds deposited sand after lower Mount Sharp had formed.

@NASA, JPL, Caltech, MSSS



NASA captures Hurricane Matthew

The strongest storm to hit the Caribbean nation in more than 50 years is captured in full force by NASA's Terra satellite, just as the cyclone made landfall on southwestern Haiti. Using its Moderate Resolution Imaging Spectroradiometer (MODIS), the Earth Observatory revealed that the cloud tops around Hurricane Matthew were very cold, at -57 degrees Celsius (-70 degrees Fahrenheit). Such chilly temperatures are known to produce heavy rainfall.

@NASA, Kathryn Hansen

Cassiopeia's unusual galactic resident

Snapped by the Hubble Space Telescope, spiral galaxy NGC 278 may look serene but it is anything but – the cosmic beauty is undergoing some fairly immense bursts of star formation, as revealed by blue-hued knots of stellar newborns that speckle the galaxy's spiral arms. The young hot stars in NGC 278 – a galaxy which rests some 38 million light years from Earth in the constellation of Cassiopeia – seem to only be forming within the inner ring of the galaxy and don't extend to its outer edges. The spiral appears to take on a two-tiered structure, where the galaxy's centre is bright and its extremities are much darker; this is thought to be the result of a turbulent merger with a smaller galaxy that was rich in gas.

© ESA; Hubble; NASA; S. Smartt (Queen's University Belfast)

Saturn's daylight on the night side

From above the gas giant, NASA's Cassini spacecraft looks down on the rings of Saturn in the shadows of the planet's night side, revealing that even here, the rings remain in sunlight – that is, apart from the portion that lies within Saturn's shadow. The planet's rings also reflect sunlight back onto the darker side of the gas giant, causing it to appear much brighter than it would otherwise seem.

A faintly visible speck is just discernible to the lower left of the rings, which is Saturn's moon Prometheus, regarded as a small satellite with a diameter of 86 kilometres (53 miles) across. The tiny moon won't fall into the darkness of the planet's shadow until the other side of its parent planet's northern summer solstice.

© NASA; JPL; Caltech; Space Science Institute



Recovery after an Orion spacecraft splashdown

In this image a group of US Navy divers, Air Force pararescuemen and Coast Guard rescue swimmers are engrossed in a mock spacecraft recovery in the Neutral Buoyancy Laboratory at NASA's Johnson Space Center, Houston. This is just one of the many splashdown tests that the Orion spacecraft will undergo: the next will see it being dropped into the Pacific Ocean just off the San Diego coast at the end of its test flight with NASA's Space Launch System. The all-new powerful rocket will pave the way for future missions, including manned missions to Mars.

LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

Universe found to contain ten times more galaxies than previously thought

Scientists say they have yet to study 90 per cent of the structures in the observable cosmos

Astronomers have long known that the universe is huge, but according to a new British-led study, they've been vastly underestimating its size. Having taken 20 years' worth of images from the Hubble Space Telescope, they managed to find a staggering 2 trillion galaxies - ten times more than the 200 billion thought to exist. The huge difference in number came after the scientists created a three-dimensional model of the observable galaxy. By accurately measuring the number of galaxies at different points in the universe's history, they were able to better understand how dense they were.

Using new mathematical models, the scientists could infer the existence of galaxies that can't be seen by current telescopes. They found that there were ten times more galaxies just a few billion years after our cosmos was formed than today, but that most are too distant and faint to be seen. "It boggles the mind that over 90 per cent of the galaxies in the universe have yet to be studied," says Christopher Conselice, from the University of Nottingham, UK. "Who knows what interesting properties we'll find when we observe these galaxies."

The results have been surprising. Not only does it show that galaxies have not been evenly distributed throughout history, it shows that significant evolution has taken place. It suggests galaxies have grown through star formation and merged with other galaxies, reducing their number. "This gives us a verification of the so-called top-down formation of structure in the universe," says Conselice.

The research, which is the result of 15 years of painstaking work, also shows the importance of Hubble in our understanding of the universe - a telescope that has been orbiting Earth since 1990. It is hoped that NASA's James Webb Space Telescope, intended for launch in 2018, will enhance the number of observable galaxies, as it is 100 times more 'powerful'.

"Galaxies have grown through star formation and merged with other galaxies, reducing their number"

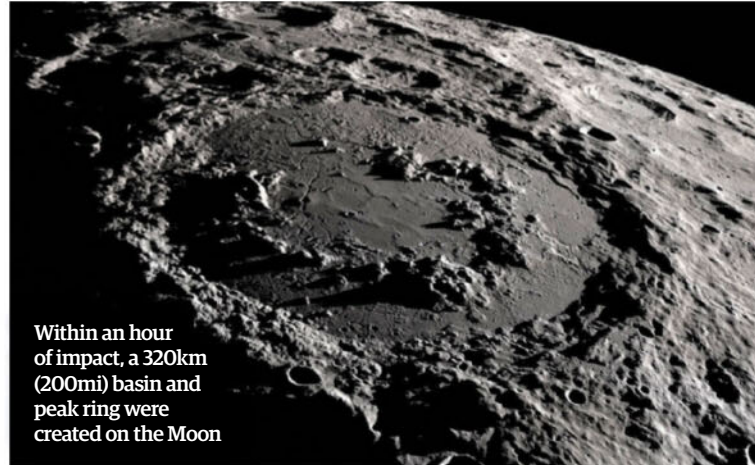
Taken by Hubble, this image shows a portion of data taken from a deep-sky census called GOODS

Moon helps to unlock secrets of dinosaur-killing asteroid

Craters on our natural satellite could aid our understanding of our planet's past

Buried underneath the Yucatán Peninsula in Mexico is the Chicxulub impact crater, a circular depression some 180 kilometres (110 miles) in diameter and 20 kilometres (12 miles) deep, which was created when a smaller body collided with Earth. It has been dubbed the dinosaur crater because the asteroid that struck this spot is understood to have hastened the end of yesteryear's giant beasts.

Gaining a better understanding of this crater is difficult though, because it is buried under one kilometre (0.62 miles) of sediment. So, instead, scientists have been turning their attention to the Schrödinger impact basin on the Moon, which is not only starkly similar but also exposed on the lunar surface, making it accessible to study using remote



Within an hour of impact, a 320km (200mi) basin and peak ring were created on the Moon

sensing techniques. "The features seen in the Schrödinger basin also paint an amazing picture of Earth's Chicxulub crater," says David Kring of the Universities Space Research Association. "Observations of the lunar basin suggest the rock in the Chicxulub basin's peak ring flowed, in part, because it was dissected into rocky blocks with reduced cohesion and possibly offset by kilometre-scale

fault motions." It has led to conclusions that the Chicxulub peak ring would have been composed of rocks from deep in the Earth's crust, which would have produced a jagged mountain range that rose from the crater floor.

"This is an excellent example of how studies of the Moon can help us better understand our planet," Kring adds, saying the Schrödinger basin holds clues to planet-building processes.

Computer glitch could have doomed ExoMars lander

The European Space Agency and Roscosmos' ExoMars lander, known as Schiaparelli, may have crashed due to a computer glitch, when it attempted to land on the surface of the Red Planet on 19 October 2016. A flaw in the software that is responsible for merging data from different sensors may have resulted in the lander's demise, causing it to 'think' it was closer to the ground than it really was, and instructing it to switch off its thrusters too early.

Exoplanet's rings turn the wrong way

The exoplanet J1407b has a ring system 200-times larger than Saturn's rings and scientists say the system will remain stable for more than 100,000 years - as long as the rings rotate in the opposite direction to how the planet orbits the star. Astrophysicists Steven Rieder and Matthew Kenworthy believe a catastrophe could have caused the rings to travel the 'wrong' way.

Starlight forms building blocks of life

Organisms are made from carbon atoms connected to hydrogen, oxygen, nitrogen and other elements, but how do these molecules form? Scientists using data from ESA's Herschel Space Observatory says ultraviolet light from stars plays a major role. "This is the initiation of the whole carbon chemistry," says John Pearson, a researcher at NASA's Jet Propulsion Laboratory.

Venus' volcanoes erupted recently

New findings suggest Venus' volcanoes were active in the relatively recent past and may still be active today. Researcher Piero D'Incecco of the German Aerospace Center, combined infrared data with high-resolution radar images from NASA's Magellan mission, to freshly analyse emission anomalies on the top and eastern flank of the volcano Idunn Mons, before identifying distinctive lava flows.

Dramatic seasonal changes seen on Saturn's largest moon

Winter is taking a grip on Titan's southern hemisphere and a strong vortex, enriched in trace gases, has developed over the south pole

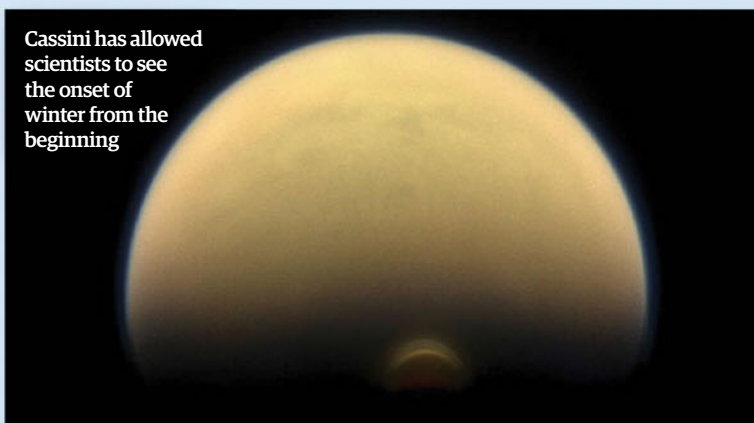
Just as we're wrapping up warm for a long, cold spell, so too is Saturn's largest moon, Titan. NASA's Cassini spacecraft has shown winter taking hold on the southern hemisphere of Titan - a polar reversal of its

atmosphere in the 12 years since Cassini arrived at Saturn.

"Cassini has been the ideal platform for observing the pattern of seasonal changes on Titan in exquisite detail and for the first time," says Dr Athena

Coustenis of the Observatoire de Paris. "We arrived at the northern mid-winter and have now had the opportunity to monitor Titan's atmospheric response through two full seasons. Since the equinox, where both hemispheres received equal heating from the Sun, we have seen rapid changes."

Over the past four years, the temperature has dropped by 40 degrees Celsius (104 degrees Fahrenheit) in the southern polar stratosphere, contrasting with a more gradual warming in the northern hemisphere - temperatures remained stable in the early spring, and have risen by only six degrees Celsius (43 degrees Fahrenheit) over the last two years. Titan experiences a pole-to-pole cycle of warm gases upwelling at the summer pole and cold gases subsiding at the winter pole.



Cassini has allowed scientists to see the onset of winter from the beginning

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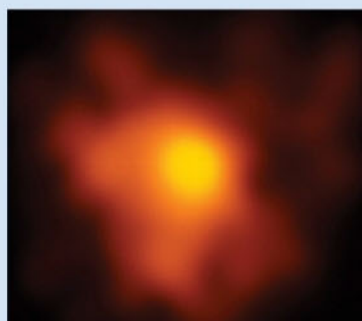
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YOUR FIRST CONTACT WITH THE UNIVERSE



Another Earth may well be orbiting our nearest neighbour, Proxima Centauri



The VLTI captures raging winds in the Eta Carinae star system

Violent collision of cosmic winds imaged in highest resolution ever

Star system Eta Carinae has been captured in fine detail

It contains one of the biggest and brightest stars in our galaxy and is 90 times the mass of the Sun, but astronomers have finally imaged the Eta Carinae star system in great detail for the first time. Using the European Southern Observatory's Very Large Telescope Interferometer (VLTI) in Chile, an international team of astronomers led by Gerd Weigelt from the Max Planck Institute, has found many insights into the binary system.

The scientists have studied the turbulent area between the stars, where high velocity stellar winds of 10 million kilometres (6.2 million miles) per hour are colliding. They were able to see an unexpected fan-shaped structure - where the wind from the smaller, hotter star crashes into the denser wind of the larger star. The VLTI combines the light from multiple telescopes, increasing optical ability, and "it has provided a unique opportunity to improve our physical understanding of Eta Carinae and many other objects," says Weigelt.

Private 'Project Blue' begins hunt for life

A new venture has been launched to find another life-bearing planet

A bid to build and launch a compact space telescope that can directly image the habitable zone of our stellar neighbours has been launched, and it is hoped that the next Earth will be found within a decade. Project Blue hopes to point its 50-centimetre (20-inch) aperture telescope at Alpha Centauri A and B and is convinced that its efforts could capture photographs of Earth-like planets that are 0.5 to 1.5 times the size of Earth.

An array of space, science and research institutions are leading the project, including the New York-based BoldlyGo Institute, Mission Centaur, the SETI Institute and the University of Massachusetts Lowell. It will involve creating a telescope equipped with high-contrast

imaging technologies embedded in a coronagraph, with a deformable mirror, multi-star wavefront control and special processing techniques.

Scientists hope it will capture a blue dot - indicative of a planet with oceans and an atmosphere. This was the colour of our planet as seen from afar by NASA's Voyager 1 spacecraft in 1990 and it's the reasoning behind the project's name. One potential candidate is Proxima b, which was seen to be in orbit around the smallest of Alpha Centauri's trio of stars, Proxima Centauri.

Project Blue hopes to launch into low-Earth orbit in 2019, with the images coming back a few years later. It will first need to find \$10-50 million (£8-40 million) of funding, though.

Water suspected on nearby metal world

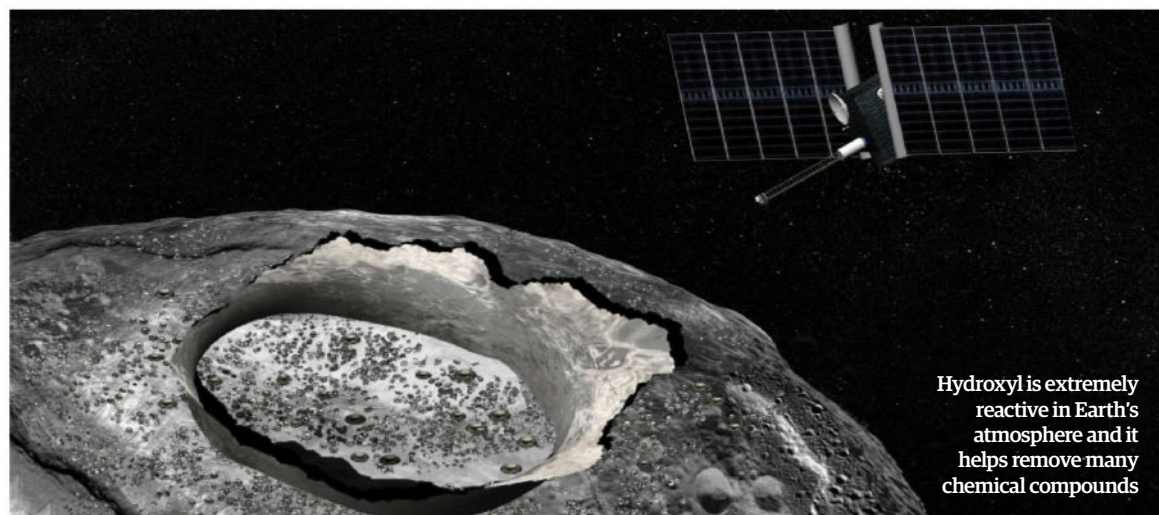
A large asteroid, thought to be the core of a destroyed protoplanet, appears to have volatiles on its surface

According to new observations, the asteroid 16 Psyche may have water on its surface, despite earlier studies showing no signs of liquid. Dr Vishnu Reddy, assistant professor at the University of Arizona's Lunar and Planetary Laboratory, says volatiles such as water or hydroxyl could be present and could show how such compounds found their way to Earth.

Psyche is one of the ten most massive asteroids in the asteroid belt and, at over 200 kilometres (124 miles) across, it is believed to be the core of a protoplanet that was destroyed by impacts billions of years ago. Scientists suggest it consists of almost pure nickel-iron metal, making it extremely rare. But as Reddy says: "We did not expect a metallic asteroid like Psyche to be covered by water and/or hydroxyl. Metal-rich asteroids like Psyche are thought to have formed under dry conditions without the presence of water or hydroxyl."

Reddy believes carbonaceous asteroids that impacted Psyche in the past may have delivered the water. "Our discovery of carbon and water on an asteroid that isn't supposed to have them, supports the idea that these building blocks of life could have been delivered to Earth," he suggests.

Alternatively, hydroxyl - a free radical of one hydrogen atom bound to one oxygen atom - could be the product of solar wind interacting with silicate minerals on the surface. The findings will be of interest to NASA, as it has a proposed mission to Psyche.



Hydroxyl is extremely reactive in Earth's atmosphere and it helps remove many chemical compounds

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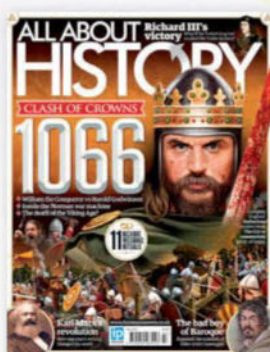
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WHAT HAPPENS WHEN WE CONTACT ALIEN LIFE?

Preparing the world for the biggest
discovery in the history of humanity

Written by Jonathan O'Callaghan



In August 2016, the world was gripped with the news that a possible signal from an intelligent alien race had been received. Picked up by a Russian radio telescope, its discoverers had no explanation for the signal, which appeared to be artificial, and suggested it could be our first sign of alien life. Alas, it was not to be. The signal, like so many before it, turned out to be interference from Earth, most likely a satellite in orbit. But the event highlighted a key point - there is a huge public clamour for finding extraterrestrial (ET) life and, when it happens, it is likely to be the biggest story in human history.

Most of our searches for intelligent alien life have been primitive and poorly funded. At the moment, perhaps the most well-known organisation leading the charge is the SETI (Search for Extraterrestrial

Intelligence) Institute in California, which performs searches with a suite of antennas known as the Allen Telescope Array. There are other groups and organisations around the world, too, involved in the hunt. For the most part, it's a small community; information is shared, discussions are held, and the ramifications of a discovery considered.

More recently, Russian billionaire Yuri Milner invested \$100 million (£820,300) in the Breakthrough Listen project, a ten-year initiative to buy telescope time and accelerate the search. The uncomfortable truth at the moment, though, is that we haven't heard anything, despite five decades of searching. With 100 billion stars in our galaxy, most thought to host at least one planet, and 100 billion galaxies in the universe, there are a lot of potential

homes for life out there. So where is everyone? "There have been a couple of times where we've got excited about something," Gerry Harp, the director of the Center for SETI Research at the SETI Institute, tells **All About Space**. "But we've never seen anything that could remotely be a signal from ET." The obvious reason why is that we just haven't looked hard enough yet. In its early days, SETI relied on a catalogue of several thousand potentially habitable systems, called HabCat, to direct the searches. But with the launch of NASA's Kepler space telescope in 2009, thousands of planets have now been found, some similar to Earth, and are attracting our attention. Once, planets were thought to be rare - now, we know they are common, even plentiful.

The stars we're looking at have changed, too. Originally, searches focused on stars like our own Sun. After all, we know Earth has life - why not look for a world similar to our own? But we now know that red dwarfs, much smaller stars, make up 80 per cent of the stars in the sky, and they might be habitable to life. So these, too, have been added to the search. Space is also unforgiving, even to radio or electromagnetic transmissions, and it's likely that if there is intelligent life out there, we'll need bigger and more powerful telescopes to listen to them. Upcoming projects like the Square Kilometre Array will further our knowledge, and bring us closer to a discovery that many think is on the horizon.

To look for signals, astronomers point telescopes to distant stars and listen for irregular patterns on a particular frequency, focusing on radio waves. If an anomaly is found, the signal is observed again, and if it disappears, it was likely just interference from something on Earth, like a satellite. But if the signal is heard five times from the same point of sky, then things get interesting. At this point, the signal would appear to be of alien origin. The SETI Institute uses an automated system to sift through thousands of signals per hour, ten per cent of which pass the first cut. None of these, of course, have ever passed the final cut, but there have been an estimated 300 million interesting signals found over the years. SETI's strict protocols, though, usually mean a

"Despite evidence suggesting there should be plenty of habitable worlds out there, we still haven't heard anything"

The Allen Telescope Array is an important tool in our hunt for alien life



Alien contact: *who will be the first to know?*

The news will hit a number of individuals before the general public is informed



1 **The discoverer**
An extraterrestrial signal is detected! The discoverer will need to verify the signal several times before revealing to others that it might be a sign of intelligent alien life.

2 **Seth Shostak, SETI Institute**
As director of the SETI Institute, Shostak is likely to be one of the heads of institutions that is asked to independently verify the signal.

3 **The President**
Once confirmed, national authorities will have to be informed of the signal. In the US, that would likely include the President, and in the UK, the Prime Minister.

4 **Ban Ki-moon, Secretary General of the UN**
Broader organisations, including the United Nations, can now start to be told about the groundbreaking discovery.

5 **You**
Last but by no means least, it will be time to publicly and officially inform the world of this amazing discovery - if it hasn't been leaked by the media already.

An alien discovery

How the detection of a signal might change life on Earth

Politics

There will be heated discussion on how humanity should be represented, if we respond.



Religion

Some religions may deny the discovery. Others may embrace it within their beliefs.



Culture

Discovering that we are not the only life in the universe would have a large impact on our culture.



Science

Perhaps the message would contain explanations of advanced scientific concepts, furthering our knowledge.



Conspiracies

If people can believe the Moon landings were faked, you can be sure some will not believe this news either.

How do we know if we've made contact?

Gerry Harp, director of the Center for SETI Research at the SETI Institute in Mountain View, California, reveals what we would expect to see



What are we looking for?

We're looking for signals that are clearly artificial. We have lots of ways we communicate using radio on Earth, and in principle, ET might use the same. But the interstellar medium - the gas between stars - messes up signals, so we look for narrow frequency bandwidth signals.

How would we verify a signal is real?

The signal has to persist. You have to look away and back with telescopes several times, until there have been five cycles. This tells you if it really is from that direction in the sky, or scattered radiation into the side of the telescope.

Have we ever had a promising signal?

There has only been one signal that passed all our automated testing. That was last year [2015], and it was exciting. We're always very sceptical about signals, but we took a look and it was a very interesting human-made signal almost designed to fool our system. It had all the right properties to look like something from outer space, but it was in fact [terrestrial] interference.

Our signals into space

The primitive attempts we've made so far to initiate contact with another race

Cosmic Call 1

Sent: 1999

Sent by: Yevpatoria RT-70 telescope
Sent from a radio telescope in Crimea, the signal targeted four Sun-like stars with four messages.

Teen Age Message

Sent: 2001

Sent by: Yevpatoria RT-70 telescope
Six Sun-like stars were targeted with a recording of a theremin - an early electronic musical instrument.

Cosmic Call 2

Sent: 2003

Sent by: Yevpatoria RT-70 telescope
The second phase of Cosmic Call transmitted photos and multimedia files to five stars.

A Message From Earth

Sent: 2008

Sent by: Yevpatoria RT-70 telescope
A signal was sent to the exoplanet Gliese 581 c, which is 20 light years from Earth.

Pioneer plaque

Sent: 1972/1973

Sent by: Pioneer 10 & 11
The twin Pioneer spacecraft carried a pair of plaques with information about humanity.

Arecibo message

Sent: 1974

Sent by: Arecibo radio telescope
A 210-byte image detailing numbers, the chemistry of DNA, the shape of humanity and the Solar System.

Golden Record

Sent: 1977

Sent by: Voyager 1 and 2
The two Voyager craft have a vinyl record on board, with sounds and images of Earth.

Across The Universe

Sent: 2008

Sent by: Deep Space Network
The Beatles' song Across The Universe was sent by NASA towards Polaris, some 430 light years away.

RuBisCo Stars

Sent: 2009

Sent by: Deep Space Network
The genetic code for a protein involved in photosynthesis was sent to three stars.

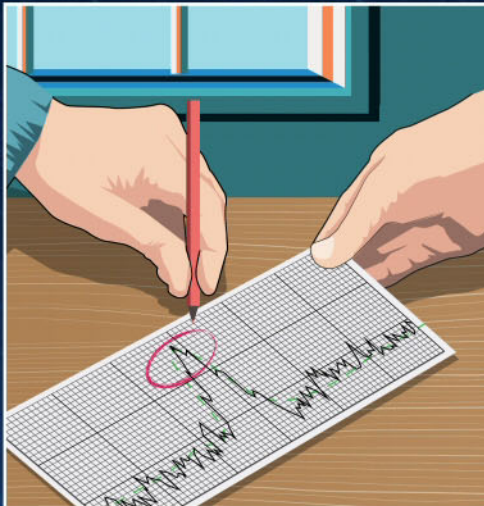
In the event of alien contact

Certain protocols have been drawn up by the SETI Institute for if an intelligent signal is found



1 Verification

While the discovery of a signal will be exciting, the first step is to make sure that the signal is actually real, and not from Earth-based interference. To do this, the discoverer must repeatedly observe the signal five times, and rule out other sources like satellites or terrestrial radio waves. If the signal is continuously seen from the same region of sky, when observing from different locations, then the discoverer can move onto the next step.



2 Get help

The discoverer now needs to inform other international observatories and institutions about the discovery. These need to all independently confirm the discovery themselves, and again verify that the signal is coming from another star, and not some sort of terrestrial interference. At this point, there should not yet be a formal public announcement, but national authorities should be informed of the discovery.



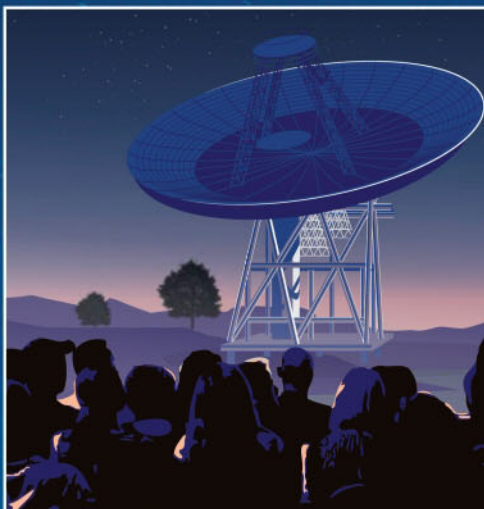
3 Prepare the world

Now it's time to tell some of the bigwigs, who can then prepare public announcements. The discoverer needs to open the findings to all observers around the world, and reveal the discovery to the Secretary General of the United Nations. SETI then lists the institutions who should be informed, such as the International Telecommunication Union, the International Astronautical Federation and the International Institute of Space Law.



5 Release and record

All data from the signal, absolutely everything, should now be collected, recorded, and stored permanently without any chance of any of the data being lost. All of this data should be given to the aforementioned international institutes, among others, and also released to the wider scientific community so that people can begin studying the signal in earnest. It's likely that, by this point, there would be a global race to be the first to decipher the message.



6 Block the frequency

Assuming the detection was made via electromagnetic signals, most likely radio waves, then steps should be taken to block and protect the frequency that the discovery was made on. This would stop other people from broadcasting on it while discussions were held across the world about what to do next. It's not entirely clear how this frequency will be blocked, but SETI recommends "convening an Extraordinary Administrative Radio Conference" to make the necessary arrangements.



7 Consider a response

The world will now be debating whether to send a response or not, so SETI recommends that international talks should begin. Stephen Hawking has argued against responding, in case the aliens are hostile, but there are many who will want to reply. After all, what's the point in making contact if we aren't going to respond? At any rate, the distances involved will likely be so large that any conversation will take place across generations, with little hope of either race visiting the other.



© Ed Crooks

4 Tell everyone

Now it's time to publicly release the find. It should be noted that the discovery is already likely to have been leaked to the media through one form or another. Nonetheless, this is the formal point where the public can be told everything. The discoverer should be given the privilege of making the announcement. They've just made the most important discovery in history - they should get some recognition for it!



8 The aftermath

The final step is to create an international committee to serve as the main focal point for the analysis of the signal. This will include experts from around the world, and "such other members as the committee may deem necessary," according to SETI. As for SETI itself, the signal would turn it from a fringe science into the most popular activity on Earth. Huge amounts of money would likely be poured into the endeavour to study this signal and, perhaps, find alien life.

signal is ruled out as being sent by aliens before the information is leaked to the public. But one day, a signal may very well pass all these tests. Despite the far-reaching ramifications of this discovery, it will almost certainly, at first, be treated like any other scientific discovery. Gradually, various institutions and organisations will be alerted, and then the fun can begin. "It would be a race to see who would be the first to make sense of the signal," says Harp. "There's a Nobel Prize in unlocking that language."

The first step will be to determine if the signal is just generic noise, like the radio transmissions we send out daily, or a directed message containing a signal. If it's the former, then the message will serve simply to tell us that we are not alone, and perhaps we could pick up more errant signals from this distant civilisation. If it's the latter, though, there may very well be some sort of key, or crib, hidden within that can help us decipher it. "If it has a crib, a directed message, maybe a hello from someone else, then we have a very good chance of deciphering it," says John Elliott from Leeds Beckett University,

who is a member of the UK SETI Research Network and has spent much of his research career working out how we'd decipher an alien signal. "It's a bit like meeting someone in the Amazon rainforest who is from a tribe that has never had contact from the outside world. You've only got to point at a tree and say 'tree', or point at rock and say 'rock', for them to understand that word means that object. That's what the crib would have to do."

Assuming we could decipher it, well, things get truly interesting. A heated debate is almost certain to spring up on whether we should respond or not. Many have argued either side of the coin, with some worrying that revealing our presence could invite hostile aliens to come here, pillage our land, and destroy humanity. Others are more optimistic, though, noting that the distances involved would likely be too great to travel over. And if we've spent so much time discovering we're not alone, why would we not respond? "I'm firmly in the camp of yes, we should reply," says Elliott. "I honestly think not to do that would be a waste. The whole point is

"The question of whether we are alone is arguably one of the greatest unsolved mysteries, and the impact of an answer would be far-reaching"



One of the objectives of China's FAST telescope is to hunt for alien life beyond the Solar System

When will we make contact?

2026



Douglas Vakoch
METI International

"My best guess for when we'll detect extraterrestrial life, if in fact we make contact in my lifetime, is by 2026 - just a decade from now"

2036



Seth Shostak
SETI Institute

"I've bet everyone a cup of coffee that we'll find a signal within two decades. If not, I'll have the opportunity to buy a lot of brew"

2046



John Elliott
UK SETI Research Network

"In 30 years, I think we'll have the dish capacity, techniques and computing power, as well as the knowledge of where is best to target"

2066



Andrew Siemion
Berkeley SETI Research Center

"If we haven't detected evidence of intelligent life beyond the Earth in 50 years, it is likely that we are essentially alone in the visible universe"

2116



Gerald Harp
Berkeley SETI Research Center

"My firm prediction is [that we will detect intelligent life] 100 years from now. I'm very confident, since I will be dead by then"

we want to know if somebody's out there. We hope they are. And you shouldn't stay silent when you see the evidence, it just doesn't sit right for me."

One group also in this camp is the Messaging Extraterrestrial Intelligence (METI), who think we should be constantly sending out directed messages, in the hope of a response, rather than waiting on the off-chance that we hear something. "If we began transmitting to nearby stars in earnest, targeting all the stars within 50 light years from Earth and waiting for a reply, 100 years from now we could be hearing back from any of a couple of thousand stars whose inhabitants had received our signal," Douglas Vakoch, president of METI tells **All About Space**.

But if an attempt at two-way communication is made, the distance of the planet will dictate what sort of conversation we can have. If it's nearby, within 50 light years, we could talk over generations. If it is much further, into the thousands of light years, then messages would only be sent back and forth over millennia. Maybe the messages would develop a sort of grand religion around them, as people waited eons for a response. "Perhaps there would be little cults or something," says Harp.

But then what? The question of whether we are alone is arguably one of the greatest unsolved mysteries, and the impact of an answer would be far-reaching. Perhaps it would change life as we know it forever, or perhaps it wouldn't change much at all. We've got no way of knowing for sure. As for SETI itself, it would turn from a fringe science into the hottest subject on Earth. "The detection would be like winning the lottery," says Harp. "But there's a good chance it would destroy the SETI Institute, and other scientific institutions [would take over]."

But despite evidence suggesting there should be plenty of habitable worlds out there, we still haven't heard anything. Maybe the route to evolving into

NASA's Kepler space telescope has revealed far more exoplanets than we thought possible



"Red dwarfs make up 80 per cent of the stars in the sky, and they look like they might be habitable to life"

sentient beings is tough, and others haven't done it yet. Earth has actually formed relatively early in the universe, about 10 billion years into its existence, if you consider the universe will stick around for a few trillion years. That's not to say there isn't something out there, though. "Making contact is incredibly likely," says Elliott. "There are many places that could support life even in our own Solar System. Not intelligent life, but life nonetheless." Maybe we just haven't looked hard enough yet, and there are others out there either waiting to hear from us, or looking on until we reach a more technically advanced stage.

But maybe we truly are alone. Considering the numbers, that seems unlikely, and it's not an opinion widely shared in SETI circles. "I used to be a lot more confident there was something out there," says Harp. "I would say that in 100 years, we could start examining a fair fraction of the galaxy with bigger and better radio telescopes. And if we don't find intelligent life, we will have to start looking in other galaxies. It would be disappointing, but I think we'll know a lot more by then." It's easy to be optimistic, though. Surely there's someone else out there - and when we find them, we'd better be ready.

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The science of *Interstellar*

Physicist Kip Thorne, the scientific advisor for Christopher Nolan's blockbuster, reveals why the plotline may not be as far-fetched as it seems

Interviewed by Rafael Maceira Garcia

You were involved in the film *Interstellar*, is the majority of the science fact or speculation?

I've written a book called *The Science Of Interstellar* and in this book I spell out which aspects of the science are real and which are speculation. *Interstellar* was designed so that approximately 50 per cent of the science is real, true and well-established and about 50 per cent is speculation. That is, speculation that's close enough to our frontiers of knowledge that it has a chance of being correct, but far enough that we can't know for sure.

Do you think that wormholes can really exist?

I think wormholes probably do not exist. The laws of physics probably forbid them, but I, along with many others, have tried for about 30 years to prove mathematically, working with the laws of physics, that they can or can't exist and we have failed. So the answer is unknown and I can only speculate that they cannot exist, but I could be wrong...

While pre-producing *Interstellar* you met with Steven Spielberg and 20 scientists of different fields to discuss the science in the film. What would you point out from that meeting?

That was a meeting to try to develop ideas for the science in the movie and to get criticisms of the ideas that we were working on. There were some severe criticisms for some of our ideas, which we then threw away or we modified, but I think, for me, the most interesting thing was just spending time with Spielberg and watching his creative mind at work. He is a very impressive man to talk to.

In your book *The Science Of Interstellar*, can our readers find the answers to questions such as, will interstellar travel be possible someday, or what does a wormhole look like?

Yes, both of those are topics that I discuss. I tried to discuss in a somewhat complete way all of the science that is connected with *Interstellar*. I try to use the book as a way to educate and answer questions for people who were inspired and made curious by the film. For me, *Interstellar* is a lure to attract people, to get them asking questions, and then my book is a hook to catch them and make

them become fascinated by the science. So I tried to discuss the science in sufficient depth for the reader to understand much of what is going on and see the beauty of it, and then the power of science.

Both black holes and wormholes have been possibly pointed to as nature's way of interstellar travel. Is it possible to compare hypothetically travelling through them?

So we know that if you can have a wormhole it would be possible to travel through. If you have a black hole it's very unlikely that you can travel through it, but you can use it for fast interstellar travel if you're clever. I discussed this in my book. I discussed something that has not, I think, been discussed before; if you have two black holes orbiting each other you can bring a spaceship in and go on a slingshot, as we call it, around one of the black holes, then toward the other one and around,

then back to the first one. If you design it so the black holes are moving toward each other, each time you launch from one to the other, you can accelerate up to very high speeds - speeds of a large fraction of the speed of light if you have a black hole binary, particularly if it's elliptical. We don't have a black hole binary so we can't do it, but I can well imagine that very, very advanced civilisations use this as a way of accelerating to very high speeds, without any discomfort for the intelligent beings and without using any fuel.

What chances do you think a spacecraft would have of surviving a trip through a black hole?

Not much chance at all. But a trip to a black hole - that is, to the vicinity of a black hole - is not a problem. If you go to the event horizon you will go inside and very probably perish, but if you go near the black hole and if the black hole is big enough,



The 2014 science fiction film *Interstellar*, directed by Christopher Nolan, aimed to use 50 per cent scientific fact and 50 per cent speculation

"I think we are likely to have a reliable understanding of the laws of quantum gravity within the next 30 years"

INTERVIEW BIO

Kip Thorne

American theoretical physicist, Kip Stephen Thorne, is best known for his contributions to gravitational physics and astrophysics. He is a longtime friend and colleague of Carl Sagan and Stephen Hawking and, until 2009, was the Feynman Professor of Theoretical Physics at Caltech, US. Thorne is one of the world's leading experts on the astrophysical implications of Einstein's theory of relativity. He consulted with Christopher Nolan on the science for the film *Interstellar*, which was released in 2014.



The premiere of sci-fi film *Interstellar*, released 2014. In the film, astronauts travel through a wormhole in search of a new Earth

the tidal forces don't kill you or don't destroy your ship. A slingshot around the black hole is a very powerful way to navigate through the universe. So, as I discussed in my book, gravitational slingshots using black holes are really a great way to do interstellar travel. In the movie, and I discussed this at great length with Christopher Nolan, he said he could only have one black hole as 100 million people were going to see this movie and 70 million of them would have had difficulty if there was more than one black hole. Nolan said: "I will describe a gravitational slingshot around a neutron star instead, because I don't want to confuse people with two black holes." So in the film Cooper talks about a slingshot orbit around a neutron star to change a spacecraft's trajectory.

In the case of surviving the trip, how do you think time would affect the spacecraft's crew?

A trip near a black hole would do what you see in the movie, [but] typically not so strong. In the movie Cooper and Brand go near the black hole Gargantua and when they are on Miller's Planet, one hour is the same as seven years on Earth. That's very extreme. It's unlikely that we have black holes that spin fast enough to allow this to happen, but for you to go down near a black hole and have time slow down by a large amount compared to back on Earth, this presumably will happen in the future, when the

"Interstellar is a lure to attract people, to get them asking questions, and then my book is a hook to catch them and make them become fascinated by the science"

human race has achieved interstellar travel and has the technology to do these kinds of trips.

How likely is it that time travel will become a real possibility in the future?

So travelling forward in time isn't very difficult, we do it every day. But travelling forward in time very rapidly is also quite possible if you have the technology to travel forward far more rapidly than you and I do. It's certainly possible. Travelling backward in time is far more difficult and perhaps impossible, but I and other physicists, as with wormholes, all work very hard to try to see what the laws of physics say about going backward in time. For example, I've discussed this in great detail with Stephen Hawking and after going back and forth we finally agreed that we don't know the answer. The answer is probably controlled by the same laws of quantum gravity - laws that come from combining

relativity with quantum physics. It's probably controlled by those laws in the same way that those laws control the birth of the universe. So we don't know. My guess is that it's not possible to go back in time, but it is just a guess.

What do you think the study of black holes may eventually offer to humanity?

I think we study black holes primarily because they are part of the universe we live in and we want to understand the universe, because they're fascinating and strange, but also because they teach us a lot about the fundamental laws of nature. If we learn in depth about the fundamental laws of nature, that is key to future technology for humans. But the greatest importance of studying black holes and other aspects of the universe to me, personally, is cultural. When we look back on the era of the Renaissance and ask what did our ancestors from that era give to us,

the answer is generally great art, great music, great architecture and the scientific method that guides how we do science. That's all cultural. And when our descendants in a few centuries look back on this era, on our era, I think they will say that we gave them the most important gift - the gift of understanding the universe and the laws of nature that govern it. For me, that is the reason why we study black holes and other things in the heavens.

Could you please explain what you call 'Einstein's law of time warps'? In your own words: "The reason that you feel the pull of gravity is because you age more slowly down here on Earth" or "Things like to live where they age the most slowly, and gravity pulls them there."

So this is actually something that Einstein realised when he was struggling to formulate his laws of gravity, which became his laws of general relativity. In 1912 as a first step he realised that, because gravity pulls things to fall from the ceiling to the floor, time must flow more slowly on the floor. You can read the details in Chapter Two of my book *Black Holes And Time Warps*. You can read Einstein's argument. So he recognised that and from knowing how strong the pull of gravity was, he actually computed and gave us a formula that tells us how much slowing of time there is here. He saw that there is this intimate connection, that the slowing of time produces gravity, or if you wish, that gravity produces the slowing of time... they go together. How much slowing of time? For every one second in space we experience 100 years of slowing on the surface of Earth. It is not much slowing, but that is the amount that's needed to produce the gravity that we feel. Einstein's formula also then enables us to say how much slowing there must be near a black hole, where gravity is much stronger. Again, the two go hand-in-hand - the slowing of time and the pull of gravity - and, of course, the slowing of time is huge near a black hole because the strength of gravity is huge.

When do you think science will have a good picture of quantum gravity and how will this knowledge help science? Will it maybe help to prove the existence of other dimensions?

So I think we are likely to have a reliable understanding of the laws of quantum gravity within the next 30 years. That is a guess. It's not within the next few months and not within the next few years, but the next several decades. There has been good progress, but still progress too slow for us to say that the experts are really close. I don't work on this, but I watch with admiration as my colleagues work on it. When we have it, I think that it will tell us about the birth of the universe, whether there are other universes, and what the connections are between universes. It will tell us whether we can go backward in time. It will tell us the full details of what happens inside a black hole. So many deep questions will be answered and controlled by these laws.

Gravitational waves are ripples in the fabric of space-time caused by some of the most violent and energetic processes in the universe. What have been the key factors in the discovery of these gravitational waves?



The Ranger single-stage spacecraft is used in the film *Interstellar* to explore other habitable worlds

"Gravitational slingshots using black holes are a great way to do interstellar travel"



Computer artwork representing a black hole against a starfield. A black hole is a super-dense object, thought to form from the collapse of a huge star

There have been a number of key factors. One is the development of superb new technology, which required several decades to develop. Another is for physicists to learn to work together in a very large collaboration because this is so complicated, so complex. These high-tech instruments are so complex and the data analysis is so complex that it requires a combined effort of 1,000 people working together in a very closely coordinated way in order to have success. It requires the leadership of people who know how to lead such collaboration. This case in particular, led us in the transforming of the Laser Interferometer Gravitational-Wave Observatory (LIGO) from a small research and development project into a large successful scientific project. When we saw these gravitational waves it also required computer

simulations [to process the information], which we would not have understood if we had only relied on the calculations of pencils and papers. We needed to have computer simulations of Einstein's equations for collisions of black holes, which produced predicted wave shapes that gravitational waves would form, to compare with the observations in order to extract the information. All of this had to come together for the discovery last September, which was very complicated and was the culmination of decades of hard work.

How has the discovery of gravitational waves impacted our understanding of the universe?

The implication is that this is the beginning of a whole new way to study the universe. Gravitational

waves will be used not just by LIGO, but also by other kinds of instruments looking at other wavelengths over the coming decades and centuries. They will be used to explore aspects of the universe that we've never dreamed of today. So it's the beginning of a very exciting future: a brand new understanding of unexpected features of the universe.

Cosmic strings are hypothetical cracks in the fabric of space. Do you think the research on gravitational waves could lead to evidence?

LIGO is actually searching for gravitational waves from cosmic strings. When two cosmic strings pass through each other, theory says with high probability that they reconnect to the point where these strings bend. Because of this reconnection, the sharp cusp as it travels down the string emits gravitational waves with a very precisely understood shape. LIGO is searching for those shapes. If we see those shapes, if we see cosmic strings, that would be a huge thing. It would be the first verification of string theory because these cosmic strings are thought to have been produced by the expansion in size and the lengthening of fundamental strings in the earliest moments of the universe - in what we call the inflation of the universe. LIGO will search for this and I think the probability of seeing them is not high but it's not zero. We have a real chance. The Laser Interferometer Space Antenna (LISA), the space-based version of LIGO, is looking at much longer wavelength gravitational waves and will have a higher probability of success. So we have hope that we will verify if the cosmic strings exist, and we may even learn more about their properties, how many exist, and their connection to fundamental strings.

Space-time is really difficult to imagine or conceive, as it is something that looks void yet can deform around objects in the universe. How would you best describe the fabric of the universe?

I really do think of it as similar to the surface of water. Water normally has a flat surface - it's not curved - but if water spins it can create a vortex, as it does in the drain of a bathtub for example, so the shape of the water forms a funnel. The shape of space is like a funnel. I have discussed this a lot in *The Science Of Interstellar*, and I visualise the shape of space by showing what it would look like to somebody who lives in the fifth dimension, who looks in on our universe and sees it looks somewhat like the funnel of a whirlpool.

How does time relate to the fabric of space and why can't time escape from a black hole?

Time and space are closely related; they are dimensions of our universe. To make an appointment to meet with a friend you have to say where in space and what time in time. In that sense, it's a fourth dimension, but the rate of flow of time and dimensions in space can be warped and are warped by large amounts of mass or energy. Around the Earth they are weakly warped, but around a black hole they are strongly warped. The warping of time is the slowing of time that we see near a black hole and the slight slowing of time near the Earth. That's just the nature of time; it is warped by mass and that warping produces gravity. Space is warped similarly.

"When our descendants look back on this era, I think they will say that we gave them the gift of understanding the universe and the laws of nature that govern it"

Matthew McConaughey stars as 'Cooper' in the 2014 sci-fi film *Interstellar*, where a crew of astronauts visit potentially habitable worlds to try and save humanity from the problems on Earth





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RON HOWARD ON MARS



The award-winning filmmaker combines drama and documentary in a unique format with the likes of Elon Musk, Neil deGrasse Tyson and Andy Weir, in an all-new series on National Geographic

What have the challenges been for you, as the executive producer of *Mars*, making narrative congruence between this contemporary science-fact documentary footage and future-set drama?

Yes, that is what's daunting about it and what's attractive and exciting. Given that our bosses have embraced the experimental side of it, I think they want to make sure that audiences also understand that this is going to unfold in an unconventional way. That's part of what's exciting about it. But I think the reason it made sense to try it was because if you just to do a mini-series about colonising Mars, you'd research it thoroughly and so forth, but in people's minds it would be like Ridley [Scott's] *The Martian*. It would be near-future sci-fi...

Or another Ray Bradbury adaptation...

Yes, right. And so we wanted it to run a little deeper than that. It's National Geographic, after all. We wanted the research and the level of acknowledgment of the real-world science to be more evident. So we initially began talking about just doing a documentary about what seems to be a sort of tipping point, in 2015 and 2016, where the world [is looking to Mars], kind of led by Elon Musk

"It's the supreme exploration of what people do when they come together as groups and ad hoc families and try to survive"

in a way, but also it has been revealed that NASA has, over the past few years - so from President Obama's statement onwards - been focusing more and more of their resources on Mars.

We felt this was kind of a tipping point in terms of initiating the impetus to really *do it*. To finally just throw down the gauntlet and make it happen somehow, and that was interesting, but pure documentary. And then [Executive Producer] Brian Grazer really had this idea of the adventure of going, and how we would depict that. And the further we went down that road, as conversations with Courteney Monroe [CEO, National Geographic Global Networks] began to evolve, this notion of approaching it in a new way came into focus. And that was to do the documentary portion, led largely by this really good documentary producer Jonathan Silberberg, through RadicalMedia and us, and do

that research, with an eye toward what the episodes might be - we didn't really define what the drama was going to be, we just estimated. Then we looked at the big picture and asked a lot of questions.

We did that and then we let the research, and the answers to the questions that the big thinkers were giving us, help guide the episodes. Then [Director] Everardo Gout did a wonderful job of letting it all be more than exposition and clinical re-enactment. Instead, he found the heartbeat of those situations, in those crises, and I'm very excited about it. I think it's going to deepen an audience's sense of the viability of the dramatised material, as it's going to be supported by these big thinkers and what they have to say. In fact, they did guide us in many ways.

What could you utilise from your experience of making *Apollo 13*?

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Well, the belief and the knowledge that the audience are far more interested in the details than you might expect. And those details don't actually detract from the drama and suspense - they can enhance it. So I think it gave both Brian [Grazer] and I confidence going into it. And then a few little tricks - a few little ideas about how to allow an audience to really understand what's going on onscreen while not betraying the authenticity and veracity of the details that you're depicting.

Are there some movies about Mars that you like or have been inspired by?

The Martian was great. But there's no one... I can't think of a movie that was actually inspiring us to believe in this, any more than *The Martian*, which I thought was a terrific movie. Director Everardo [Gout], the production designer, our research teams,

the scientists and the astronauts who helped - they're the ones that helped us shape the drama. And Stephen Petranek's book, *How We'll Live On Mars*, was sort of the first foundational narrative jumping-off place. Because while he didn't go into a lot of detail, he also became a part of the production and had all of his research about the kind of crises that humans are very likely to face. We made a big list of all the things that could kill you up there and there were far more than we could put into this six-hour series! 'Number 45! Rock slide!' We could do years of this stuff based on the punch list of expected threats to colonisers.

Considering films of yours such as *Apollo 13*, *Rush*, *In The Heart Of The Sea* and *A Beautiful Mind*, are you driven to explore what makes humans want to push themselves to the edge,

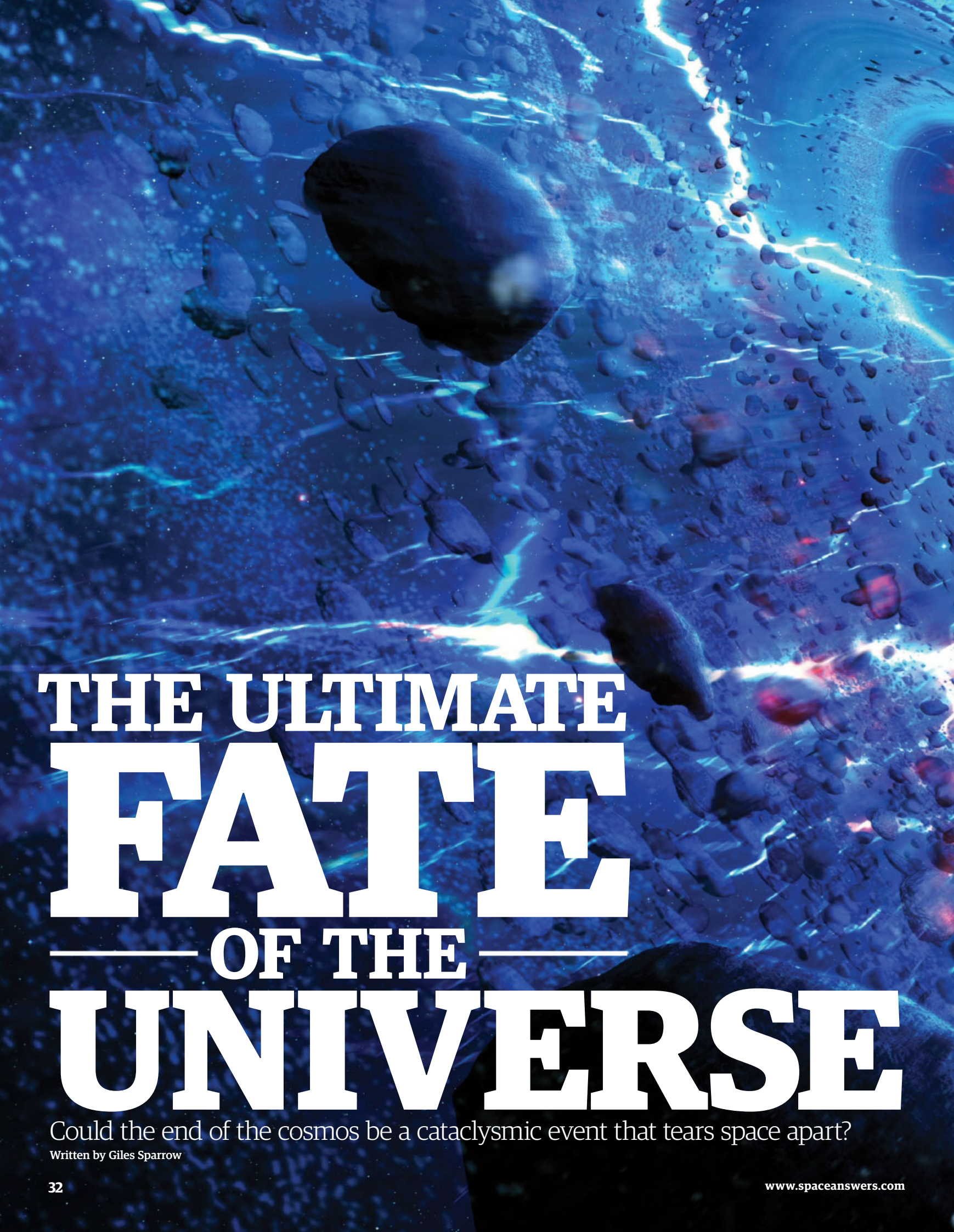
and beyond, possibly at the risk of their own sanity or life?

It really fascinates me. To me, it's the supreme exploration of what people do when they come together as groups and ad hoc families and try to survive. I always find that pressure to be emotional, dramatic and very relatable. In most of our lives, the big pressures are coming together to deal with some sort of problem in the family, neighbourhood or at work - or helping one another survive a whale attack, Apollo 13 or a return to Mars. It is what I liked about the Beatles project I just did. It's about a group of guys who have to lean on each other in order to get through something, which they had no idea could be as tumultuous as it turned out to be.

Why do the public have to watch *Mars*?

I think that the *Mars* series is going to stimulate the imagination and the intellect of an audience. So it's kind of two ways of really engrossing you and entertaining you. I think the documentary portion reinforces the drama, while the drama underscores the emotional content of the documentary material - I think that is what's so unique about it and really makes it something [special].

"We let the research, and the answers to the questions that the big thinkers were giving us, help guide the episodes"



THE ULTIMATE FATE — OF THE — UNIVERSE

Could the end of the cosmos be a cataclysmic event that tears space apart?

Written by Giles Sparrow



Fate of the universe

How will the universe end? It's a question that has fascinated mystics and philosophers for centuries, but one that's only interested astronomers in the past few decades. For a long time, scientists assumed that the cosmos was eternal, with neither a beginning nor an end - it was only in the mid-20th century, after growing evidence convinced astronomers that the universe began in a Big Bang, that the possibility of an equally finite cosmic doomsday was considered.

The evidence of modern astronomy shows us that the universe has changed radically throughout its history and will continue to do so into the future - not only is space still expanding but the matter inside it is continuously evolving, too. Enormous clouds of light hydrogen and helium have condensed to form stars whose nuclear furnaces fuse them into heavier elements. The death of stars scatters these heavier elements across space, where they are incorporated into later generations of stars and planets. This process of enrichment is slow, but over billions of years, it consumes the cosmic fuel supply of light elements, leaving matter concentrated in forms that can no longer give rise to shining stars. In

a trillion years or so, if the universe continues in its present state, the last stars will falter and the cosmos will be plunged into perpetual cold and darkness - a 'Big Chill'. But that's not the only possibility - cosmologists who look at the overall universe rather than the material within it have imagined several other outcomes.

Investigating the fate of the cosmos relies on the ideas of general relativity - the model of matter, space and gravity discovered by Albert Einstein. According to Einstein, the attractive force of gravity is a distortion of space created by the presence of mass. All the matter in the universe should exert a gravitational force that pulls it back together, slowing the acceleration triggered by the Big Bang. If the total mass and gravity are strong enough, the acceleration

might even go into reverse, drawing matter and space itself back to a super-dense, superheated 'Big Crunch'.

"Up until 20 years ago, every student cosmologist was taught that the geometry of the universe was the arbiter of its fate," explains Robert Caldwell of Dartmouth College, New Hampshire. "The universe would either expand forever or collapse back into a Big Crunch - and if it expanded forever, it would be doing so at an ever-decreasing rate." Deciding which of these two fates is the true destiny of the universe depends crucially on the amount of mass in the universe, and measuring the combined amount of matter (both normal 'baryonic' matter and the non-luminous, transparent 'dark matter' that only reveals its presence through gravity) became a key challenge for astronomers. Until the mid-1990s it seemed that

"The universe has changed radically throughout its history and will continue to do so into the future"

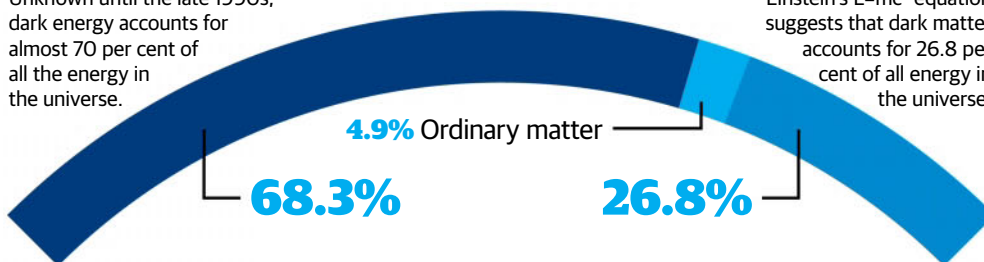
Dark energy vs dark matter

Dark energy

Unknown until the late 1990s, dark energy accounts for almost 70 per cent of all the energy in the universe.

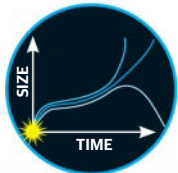
Dark matter

Einstein's $E=mc^2$ equation suggests that dark matter accounts for 26.8 per cent of all energy in the universe.



Supernova evidence

The key evidence for dark energy comes from Type Ia supernovae - collapsing stellar remnants that always reach the same peak brightness.



Expansion curves

The nature of dark energy affects the universe - whether the expansion triggered by the Big Bang reverses, continues or accelerates.



Heading for a Big Rip?

There's evidence that the effects of dark energy have grown stronger in the past 7bn years. If this continues, cosmic acceleration could ultimately tear everything apart.



Alternative explanations

Some cosmologists think the evidence for dark energy could be explained by modifications to known theories of gravity, removing the need for a Big Rip.

Missing mass

In the 1930s, Swiss astronomer Fritz Zwicky first identified huge amounts of dark matter through the motion of galaxies within clusters.



Galactic rotation

In the 1970s, astronomers found that the gravity of unseen matter also affects the orbits of stars in our galaxy and other galaxies.



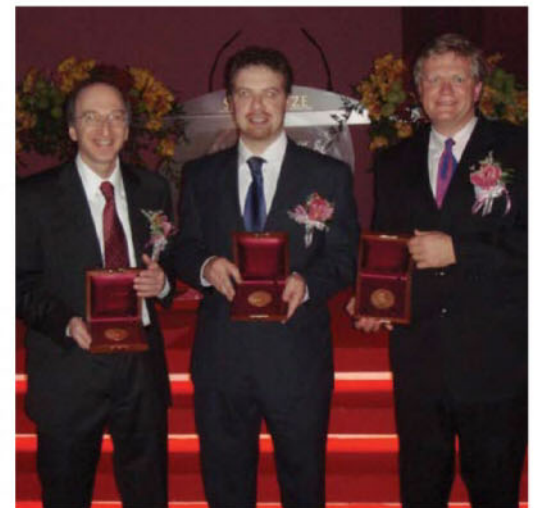
Planets or particles?

Some dark matter is probably 'normal' dense, non-luminous stuff, like planets or black holes, but most is thought to be in the form of diffuse clouds of exotic, undetectable particles.



Gravitational lensing

Astronomers can trace the distribution of dark matter by measuring the way galaxy clusters warp and deflect light from more distant objects.



Saul Perlmutter, Adam Riess and Brian P. Schmidt won the 2006 Shaw Prize in Astronomy and the 2011 Nobel Prize in Physics for their discovery of dark energy



When a white dwarf's mass is over 1.4 times the Sun, it cannot support itself and collapses in a violent explosion

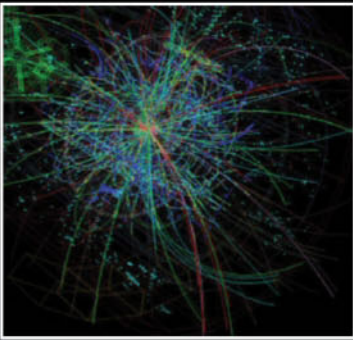
Fates of the universe

Depending on the exact properties of dark energy, the future of the universe could go in one of four directions

Big Chill

100 trillion years from now

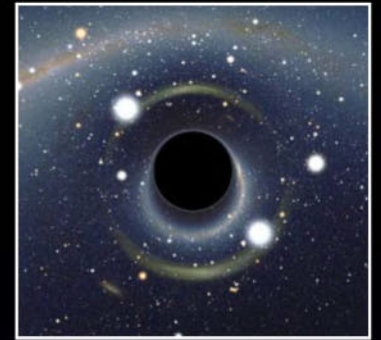
If dark energy is constant, then depending on the balance of mass in the cosmos, the universe's expansion might continue forever, but at an ever-slowing rate. Over 100 billion years or more, the stars would burn out and leave the universe in darkness, but it would take a thousand times as long for matter to cool and decay into subatomic particles in a 'Big Chill'.



Even particles such as protons are unstable on the longest timescales - eventually all matter will disintegrate into tiny, cold subatomic particles

Modified Big Chill

If dark energy remains a feature into the far future, then the universe will continue to expand at a gradually increasing rate. This would pull apart structures such as galaxy clusters, which are not gravitationally bound, before the long, slow decline of the Big Chill takes hold.

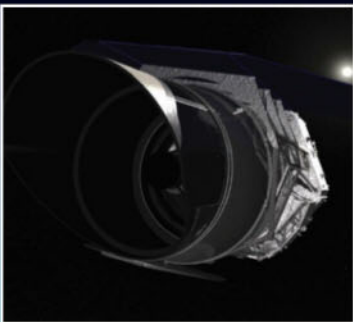


Given a long enough time, even black holes are expected to lose mass through a mechanism known as Hawking Radiation

Big Rip

At least 2.8 billion years from now

If dark energy continues to increase in strength and density, its influence will begin to be felt on smaller and smaller scales until it pulls apart galaxies, solar systems, and even planets. Eventually, all matter will be shredded into tiny, subatomic particles. Dr Diego Sáez-Gómez's work shows that this can't happen for at least another 2.8 billion years, and there are many experts that think it would only occur on a much longer timescale.

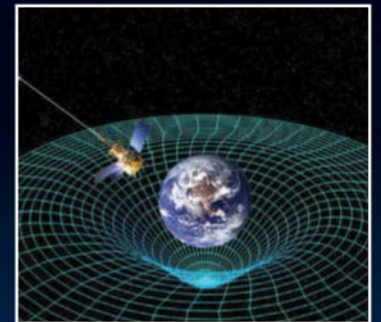


NASA's upcoming WFIRST telescope will carry out detailed surveys of supernovae and galaxies, revealing more about the nature of dark energy

Big Crunch

100 billion years from now

If the strength of dark energy goes into an unexpected decline or even goes into reverse, then gravity could still win its battle with cosmic expansion. It would pull our universe back into an ever-shrinking region of space, eventually creating a fiery 'Big Crunch' - out of which another universe might emerge in a so-called 'Big Bounce'.



A Big Crunch would be a natural consequence of the way matter warps space-time, as measured recently by NASA's Gravity Probe B

the overall mass of the universe hovered right on the border between Big Chill and Big Crunch outcomes. But in 1998, astronomers made an astonishing discovery: the expansion of the universe is not slowing down at all - instead, it is accelerating.

Two teams of astronomers were using an ingenious method for checking the current rate of cosmic expansion, known as the Hubble Constant. The value for this constant had been calculated with some precision in the nearby universe, but Adam Riess and Saul Perlmutter's groups both wanted to check it over much longer distances. To do this, they scoured faint, distant galaxies for Type Ia supernovae - eruptions caused by the sudden collapse of a dense white dwarf into an even denser neutron star. These violent events release enough energy to outshine an entire galaxy for several weeks, and always reach the same peak brightness - both teams hoped to use them as 'standard candles' to work out the distance to their host galaxies and then (by measuring the speed of motion away from Earth), to calculate the rate of expansion. The researchers expected to measure how much today's rate of expansion had slowed. Instead, they found that the distant supernovae were fainter than expected - an effect that could only be explained if the universe today is growing *more* rapidly than in the past.

Dark energy is one of the greatest scientific discoveries, but it remains a puzzle for cosmologists and physicists alike. It only makes its influence felt over the greatest cosmic distances, and appears to act as an energy field permeating space-time itself. It accounts for 68.3 per cent of all energy in the universe, and at first glance, it seems to settle the argument about possible fates for the universe. "The discovery of cosmic acceleration changed everything," says Caldwell, "but it also taught us that it's hard to make definite predictions. The expansion of the universe is accelerating today, so we have a wider set of options - it could expand forever at an accelerating rate if dark energy persists, but perhaps dark energy could turn off at some point, or its properties could diminish so that the acceleration weakened or disappeared - we might go into a deceleration again. I would call all of those scenarios Big Chills - the timescales are so great that the universe will become a cold and lonely place over many aeons."

What is phantom energy?

The phantom form of dark energy is defined in terms of a cosmic "equation of state," as Robert Caldwell explains: "The equation of state is the ratio of the pressure to the energy density - so if we plug it into certain equations it can tell us how stuff behaves. When this parameter equals -1, that corresponds to the case of a cosmological constant - the energy density and negative pressure are constant everywhere, so there's tension throughout the universe. But if the equation of state is more negative than -1, that corresponds to what we call phantom energy. The abundance of the energy density is growing with time and the repulsion is having a greater and greater effect on the rate of expansion in a runaway process."

Heading for a Rip?

The presence of dark energy has a profound effect on the evolution of our universe, from the earliest times to the far future

1. Big Bang

The universe originated as a hot, dense point of matter and expanding space-time some 13.8 billion years ago.

2. Early inflation

A fraction of a second after the Big Bang, the universe went through a sudden and violent phase of expansion called inflation - could it be linked to dark energy?

3. Transparent universe

380,000 years after the Big Bang, subatomic particles combined to form atoms, and the universe became suddenly transparent.

4. First galaxies

The first stars and galaxies coalesced around filaments of matter that had already begun to form through Baryon Acoustic Oscillations in the early universe.

5. Slowing expansion

For the first half of cosmic history, the expansion imparted by the Big Bang seems to have slowed down, as we would expect from the influence of gravity.

7. Torn apart

If dark energy continues to strengthen, then billions of years into the future, it will begin to drive objects apart on ever-smaller scales.

8. The end of everything

In a Big Rip, dark energy would ultimately become infinite, overwhelming the integrity of space-time itself and tearing the cosmos to shreds.

6. Intensifying energy

About 7 billion years ago, dark energy grew strong enough to overcome gravity and cosmic expansion began to accelerate once again.



© Tobias Roetsch

The expanding universe

Astronomers use a wide variety of techniques to measure their way to the edge of the cosmos and find traces of dark energy

Galactic Cepheids
Direct measurements reveal patterns in star behaviour that can be used to extend the distance ladder, such as Cepheid variables.

Standard candles
Cepheids are unstable yellow supergiant stars that pulsate in a cycle, which relates to their intrinsic brightness and reveals their distance.

Exploding stars
Type Ia supernovae are far rarer than Cepheids, but these stellar explosions also shine with a known brightness so they can be used for distance estimates.

The redshift shortcut
For the most distant parts of the universe, astronomers assume that objects with larger redshifts are further away. Type Ia supernovae allow them to calibrate this rule of thumb.

Parallax measurements
The most direct measurements in our neighbourhood rely on parallax – the shift in position of stars when viewed from opposite sides of Earth's orbit.

Gaia's breakthrough
The parallax effect is tiny, but ESA's advanced Gaia satellite is expanding its usefulness across much of the Milky Way.

Limits of measurement
Cepheids are only visible in fairly nearby galaxies, but Type Ia supernovae can be seen over much greater distances. However, they require automated large-scale surveys to capture them.

Hubble's law
Cosmic expansion means that the further away a galaxy is, the faster it is moving away from us. The Doppler effect stretches the light of such fast-retreating objects in an effect called redshift.



If dark energy accelerated in the near future, we would find our skies growing dark as other galaxies and stars were pulled further and further away

“Distant supernovae were fainter than expected – an effect that could only be explained if the universe today is growing *more* rapidly than in the past”

In 2003, however, Caldwell was lead author on a paper that proposed an alternative: phantom energy, which has the potential to rip matter and space apart. The simplest form of dark energy is known as a ‘cosmological constant’. It increases as the universe grows and the volume of space becomes larger, but the strength of energy in a given volume of space does not change. The ‘phantom energy’ paper suggested that dark energy might evolve and strengthen over time. “In a phantom energy situation, the density of dark energy is growing with time and the repulsion is having a greater and greater effect on the rate of expansion,” outlines Caldwell. “It’s possible that geometry still plays a role and there could still be a Big Crunch in the future. But if dark energy continues to grow stronger and more repulsive, then we could have a totally different fate of the universe – a Big Rip. In that case, the future is not only a cold

and lonely place, but a cold, lonely and *finite* place.” Caldwell’s 2003 paper was largely hypothetical, but it found support in 2006 when astronomers from the University of Chicago looked at the data and found strong signs for two distinct epochs of cosmic history – an early period when the expansion of space was slowing as expected from the Big Bang, and a more recent phase (the last 7 billion years), in which acceleration has taken hold. It seems that dark energy has grown stronger in the past, suggesting that it will continue to do so in the future. So what would a Big Rip actually involve?

“At present, the expansion of space is negligible on the scale of objects like our Solar System or galaxy,” says Caldwell. “It’s only when you get to objects larger than galaxy clusters that you can see the expansion pulling clusters apart when we might expect them to fall inwards. Einstein tells us that gravity is geometry,

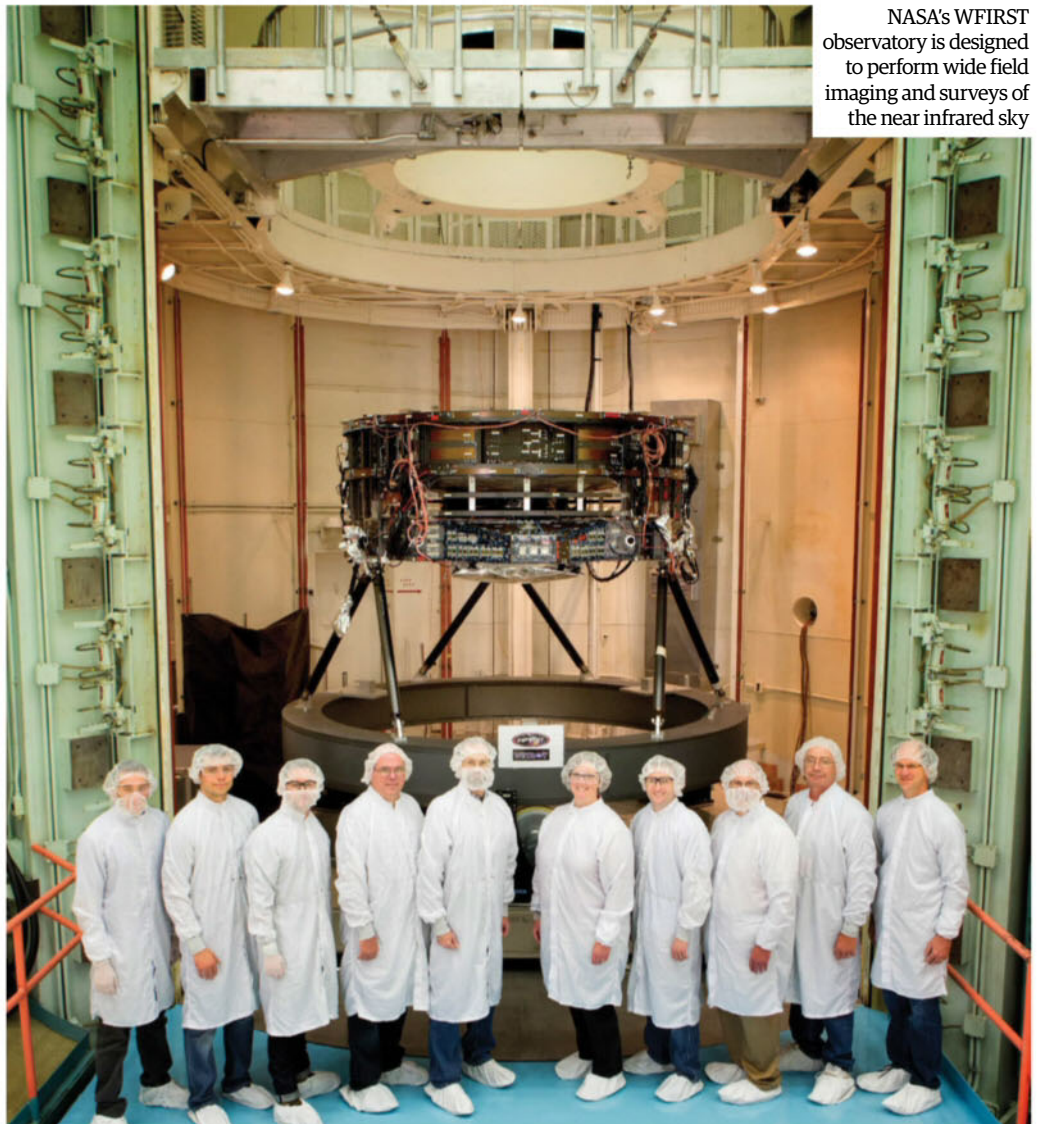
but in some ways, you can think of the expansion of the universe as a force pulling distant clusters apart. In the Big Rip scenario, that force gets stronger and not only pulls clusters apart more rapidly, but gets strong enough to pull apart gravitationally bound systems - even objects that are bound by smaller-scale, stronger forces such as electromagnetism and nuclear forces. It will pull apart stars like the Sun, planets like Earth, and if you take it to its logical conclusion, space itself. And the remarkable thing is that it happens in a finite amount of time."

The idea of everything we know being ripped to shreds by an unstoppable force is a sobering thought - and one that raises the obvious question of how soon such an apocalyptic scenario might take hold. Fortunately, since dark energy was first discovered, cosmologists have been hard at work probing its nature, refining their measurements, and narrowing down the options. Dr Diego Saez-Goméz of the Institute of Space Sciences, Barcelona, and his colleagues recently came up with a possible answer that suggests we don't have to worry just yet. "The main problem of dark energy is the difficulty of distinguishing among the many possible models that describe such unknown components of the universe," he says. "But in the case that the 'true' model would lead to a type of future singularity, we found that this is very unlikely to occur before 0.2 times the age of the universe - about 2.8 billion years from now. But this conclusion is based on assumptions about dark energy which might not be true."

Saez-Goméz and his colleagues used three lines of evidence to inform their models of cosmic evolution - Type Ia supernovae (used to discover dark energy); measurements of the Hubble Constant; and Baryonic Acoustic Oscillations (BAOs). "In the same way as Type Ia supernovae are standard candles, BAOs are considered a standard ruler," explains Dr Saez-Goméz. The oscillations were ripples created in the early, opaque universe when photons were trapped in interactions with densely packed matter. "When the universe cooled enough and the photons were released [in the recombination era], the oscillations became frozen: as the universe expanded, they did as well," he continues. Fortunately, the distribution of oscillations at the time of recombination is preserved in the cosmic microwave background radiation. "We can compare the size of the sound horizon at the time of recombination with today, to see how the universe has evolved," says Dr Saez-Goméz.

Of course, just because the lower bound for a Big Rip to occur is 2.8 billion years away, that doesn't mean it couldn't be much further off - or indeed not happen at all. "I think Diego's estimate is a little too low," says Caldwell. "Based on the supernova and Hubble Constant data, we'd have a lower bound of 12 billion years." So far, then, a lot of the evidence seems to point in the direction of a Big Rip as the fate of the universe, but the case is far from closed, and the quest to learn more about dark energy and its evolution is driving cosmologists to develop ever more ingenious ways of probing the history of our universe. "Almost any observational phenomenon in cosmology will be influenced by the expansion rate," adds Caldwell. "Sometimes the link is not so direct, but the threat of phantom dark energy makes everyone work a little harder!"

NASA's WFIRST observatory is designed to perform wide field imaging and surveys of the near infrared sky



Surveys like this reveal patterns of galaxy distribution that are magnified versions of the original BAOs, revealing the rate at which the universe has grown



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Ice houses on Mars

Sending materials to the Red Planet is costly so we'll need to build future bases with local materials. Printing with ice may be the answer

When humans were exploring Earth we didn't bring everything we would ever need on the journey with us; we lived off the land, and if we are to settle elsewhere in the Solar System, we will need to learn to do the same in less hospitable environments. One option is building planetary bases, or at least radiation shielding, from local rock. Many studies have looked at this, from piling soil over space capsules to making extraterrestrial concrete. But these methods require substantial in-situ processing and produce bases that would feel like caves. But the winner of NASA's Habitat Challenge may have a material that makes it much easier to build on other planets, and produce structures that are light, pleasant and outward-looking: 3D-printed ice.

The NASA challenge was to "develop architectural concepts that take advantage of the unique capabilities 3D printing offers, and to imagine what habitats on Mars might look like using this technology and in-situ resources". Space Exploration Architecture (SEArch) group, and CloudsAO architects in New York, won the competition with their ingenious Martian Ice House; indeed, the combination of 3D printing and using water as a building material have particularly cooperative benefits for the Mars environment.

Evidence suggests water is abundant in the Martian soil, and Mars' low pressure and temperature can be used to help collect it. If ice in the soil is dug up and exposed to the Martian atmosphere, the low pressure causes it to sublime - it goes directly from a solid into a gas without melting into a liquid. So robots can collect water by simply scraping away the soil from an area of ice and then collecting it as water vapour. More importantly, if held at the pressure required inside a base, but left at Martian temperature, liquid water will freeze instantly into a permanent structure; and water is brilliant radiation

shielding, stopping hazardous ultraviolet (UV) and cosmic radiation but while letting in visible light.

A Martian Ice House would start with a four-storey cylindrical lander; after touch-down, robots will first sinter the soil (fusing it with a laser, but without fully melting it) to form a foundation around the bottom of the lander. These robots will then go and collect water from the surrounding area and fill up a reservoir back at the lander. Meanwhile, an EFTE membrane (also used to cover the National Space Centre and The Eden Project) is inflated around the lander and its new foundation. Printing robots then spray water onto the inside of the membrane; the film protects it from the low pressure outside while preserving the cold so it freezes instantly into shape. The robots will add fibres into the ice to increase its strength, so the ice walls will be self-supporting. They will also print an integral helical ridge on the inside for the robots to climb up.

Once the outer shell is formed, the same robots will print an inner ice shell around the lander, lining it with Aerogel insulation (a silicon or carbon foam that is 97 per cent empty space) so that the inner chamber can be at 20 degrees Celsius (68 degrees Fahrenheit) without affecting the ice. Plants can be grown inside the inner chamber, producing oxygen, food and simply a nicer living space, while the outer chamber provides extra space for managing the balance of oxygen, radiation protection, and a general area that the crew can use with only oxygen masks, not pressure suits. Natural light will diffuse through the whole base, and ice-protected EFTE windows will provide outside views. All these features should combine to make a much more pleasant and convenient living experience for Mars' first settlers.



iBot

These robots spray the collected water onto the inside of the membrane to build up the ice wall. They would have nozzles for water, fibre reinforcement and insulation.



EFTE membrane

This is the inflatable pressure wall that forms the outside of the base. Once finished it protects the ice from the atmosphere to stop it sublimating again.

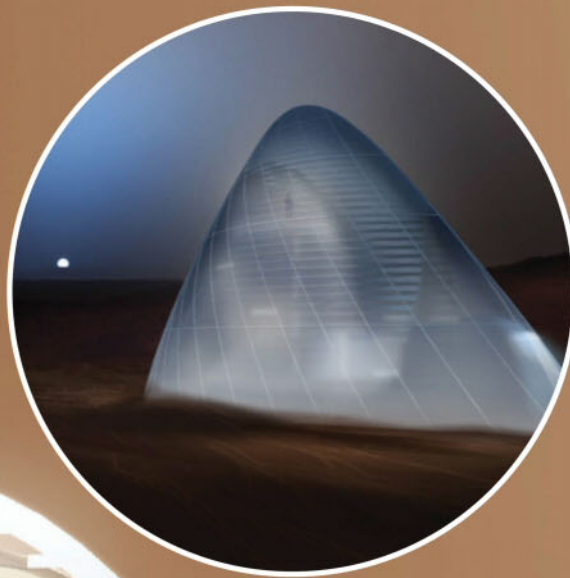
The backyard

The base is surrounded by the outer shell, which will enclose an unheated but pressurised space that the settlers can use without full space suits.

For more information please visit:
www.marsicehouse.com

Aerogel insulation

The inner core is surrounded by transparent insulation to keep heat in and protect the ice walls. This would be made of carbon or silicon Aerogel.



“The robots will add fibres into the ice to increase its strength, so the ice walls will be self-supporting”

Living space

Natural light will filter all the way into the base, relieving claustrophobia and allowing the cultivation of plants and crops.



Ice wall

The finished ice structures provide load bearing walls and effective radiation shielding, blocking UV and cosmic rays while letting visible light in.

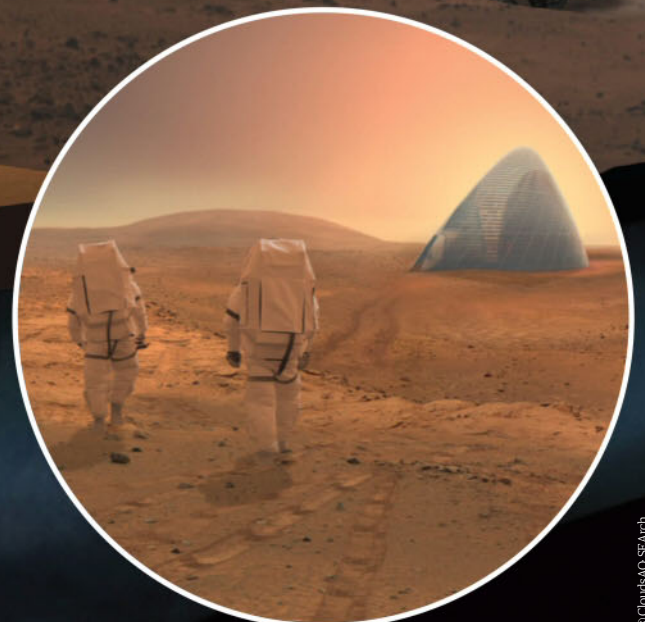
WaSiBos

The water-mining and sintering robots will fuse the local soil together into a solid foundation by melting it with a laser. They will then go and collect water ice from the surrounding area.



Core lander

A tall, thin, cylindrical lander provides the basis for the habitat, bringing the construction equipment, life support, communication and electrical systems.



Explorer's Guide Europa

One of the most fascinating elements of our Solar System, this Jovian moon could hold the key to life beyond Earth

Europa may only be the sixth closest moon to Jupiter - and the smallest of the gas giant's four Galilean satellites - but its impact on astronomy and how we perceive our place in the wider cosmos has made it one of the most important celestial bodies in our little corner of space. Discovered by pure chance on 8 January 1610 by Galileo Galilei himself, the Jovian moon wasn't just a surprising encounter - it changed the very fabric of our place in the universe and rocked everything from the calculations of science to the theology of faith.

For centuries, humans had believed the Earth was at the centre of the known cosmos - God's greatest creation turning at the heart of his canvas of stars - but the teachings of Aristotle were suddenly in doubt. If Galileo's observations were correct, and the new moon - named Europa in honour of one of Zeus' lovers - did indeed orbit the planet Jupiter and not our celestial home, then perhaps the Earth wasn't the

core of the heavens. It was a claim that brought the might of the Church down upon the Italian physicist and nearly destroyed his career and his livelihood, but it was one that refused to die. It would go on to form the groundwork for a new understanding of the stars.

Europa, without a hint of hyperbole, helped reinvent astronomy and infuse academics with a new desire to study it and the cosmos with even greater clarity. And when the Voyager 2 probe finally snapped Europa up close in 1979, that fascination was deepened further still as we discovered the icy satellite was almost entirely smooth. With no mountains or signs of meteor impacts, the surface of the icy crust suggested a liquid ocean beneath and, perhaps, the potential for life beyond our blue-green home...

How to get there

1. Lift off

To break free of the Earth's gravitational pull and leave its atmosphere behind, the craft needs a primary rocket with some serious oomph, such as the Titan IIIE that carried Voyager 2.

2. The long journey begins

With the 628mn km (390mn mi) journey from Earth to Europa now ahead of it, the craft will power down to auxiliary systems and begin its foray into deep space.

3. Course correction

Like almost any deep space mission, a craft travelling as far as Europa is likely to drift slightly off course during its journey, so course corrections will be made from mission control.

4. Jovian encounter

Based on current fuel advances, the flight to Jovian space will take just under a year and a half, with the craft encountering Europa's orbital core first - the mighty Jupiter.

5. Arrival at Europa

After 600 or more days of travel (the time varies due to orbits of Jupiter and Earth around the Sun), the craft will arrive at the smooth, icy presence of Jupiter's smallest Galilean moon.

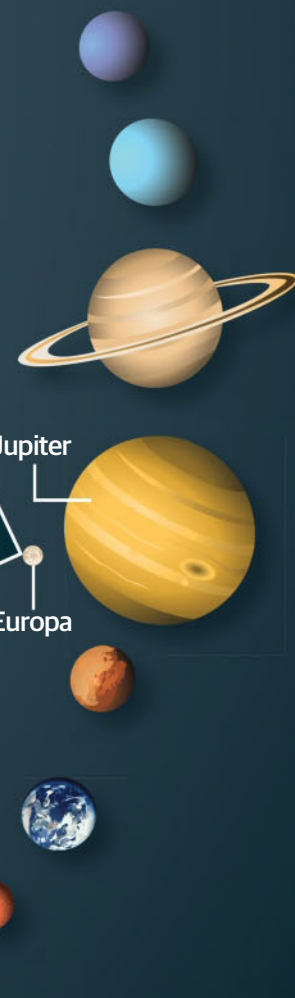
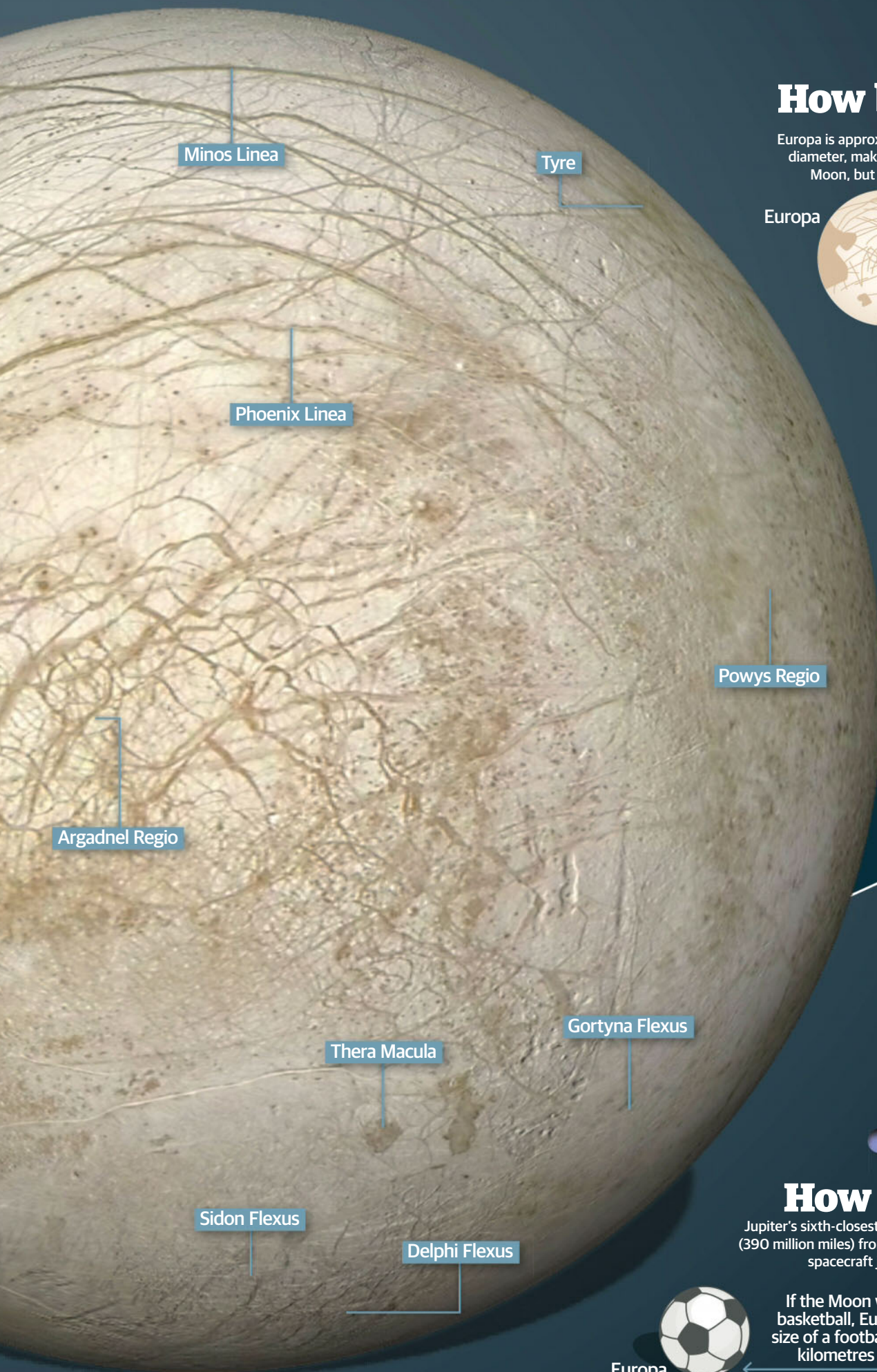
Belus Linea

Dyfed Regio

Pwys

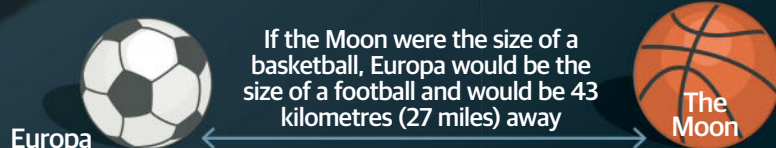
How big is Europa?

Europa is approximately 3,100 kilometres (1,900 miles) in diameter, making it slightly smaller than the Earth's own Moon, but noticeably larger than dwarf planet Pluto.



How far is Europa?

Jupiter's sixth-closest satellite is located 628 million kilometres (390 million miles) from Earth. With this in mind, it would take a spacecraft just over 600 days to reach the icy moon.



Top sights to see on Europa

Europa may be famous for its beautiful smooth appearance, but that icy surface is home to some memorable and fascinating topographical monuments. A series of dark lines and ridges called lineae criss-cross its entire globe like a patchwork of scars. With so few impact craters from asteroids and meteorites, Europa's lineae have become one of its most iconic sights. These ridges come in many forms, including the flexus - long curved ridges in a scalloped pattern. There are many theories relating to the origin of these ridges, but the most widely accepted relates to a series of eruptions of warm ice as the Europan crust broke open to expose warmer layers beneath. This process is also found on Earth as oceanic ridges shift and move, lending more credence

to the theory that Europa has a giant subsurface ocean beneath its icy crust. The areas where these lines and ridges intersect are known as chaos terrain and they can be seen all over the moon's surface.

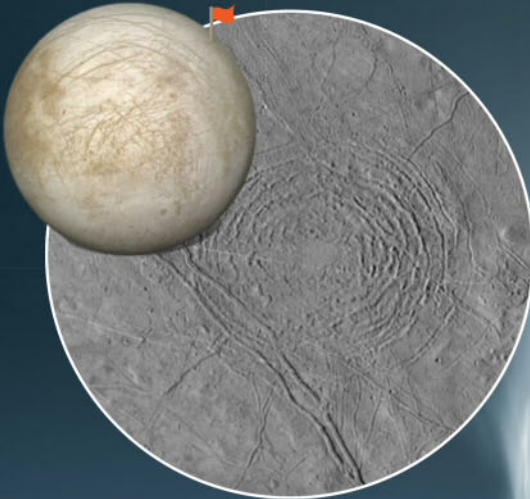
Europa is also home to a series of elliptical lenticulae, known more commonly as maculae, which are usually represented by dark spots on the surface of the moon. The darkness of these features usually means they're either small domes or deep pits, which create noticeable shadows on the images captured by Voyager 2 and other passing probes. These geographical attributes are also named after places and characters from European legends and stories, including Celtic and Greek mythologies. For instance, the Conamara, Rathmore and Arran chaotic terrains

are named after locations found primarily in Celtic myths. Alongside these fascinating surface features, Europa is also believed to possess a subsurface liquid ocean beneath the mantle. The general consensus among scientists is that this ocean retains its liquid state due to tidal flexing. This form of heating is caused by the forces pulling Europa between Jupiter and the other Galilean moons, creating an orbital and rotational heat that's absorbed through the surface.

A recent NASA study has revealed Europa's subsurface ocean erupting into the moon's atmosphere in great plumes of vapour. Not only is this an incredible sight, but it will enable future missions, such as NASA's Clipper mission, to study its composition without having to drill through the ice.

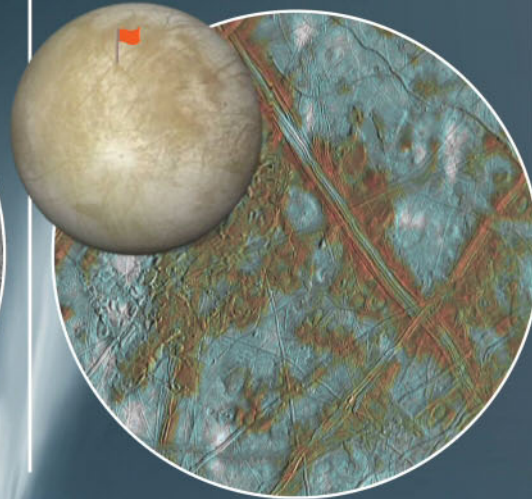
Tyre crater ring

This multi-ring impact feature measures 40 kilometres (25 miles) across. The original crater rim is located just inside the innermost concentric ring.



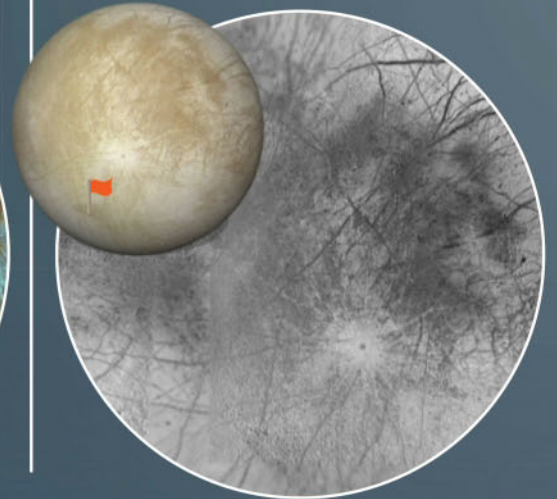
Conamara Chaos

One of Europa's most impressive attributes, the Conamara Chaos is one of the largest collections of interconnected ridges and geographical scars.



Moytura Regio

Europa itself was divided into eight regions based on the data observed by Pioneer 10 and Voyager 2. The Moytura Regio was named after a Celtic battle site.



Vapour plumes

In one of Europa's most startling natural features, several plumes of water vapour erupt from the ice mantle surface with incredible pressure.

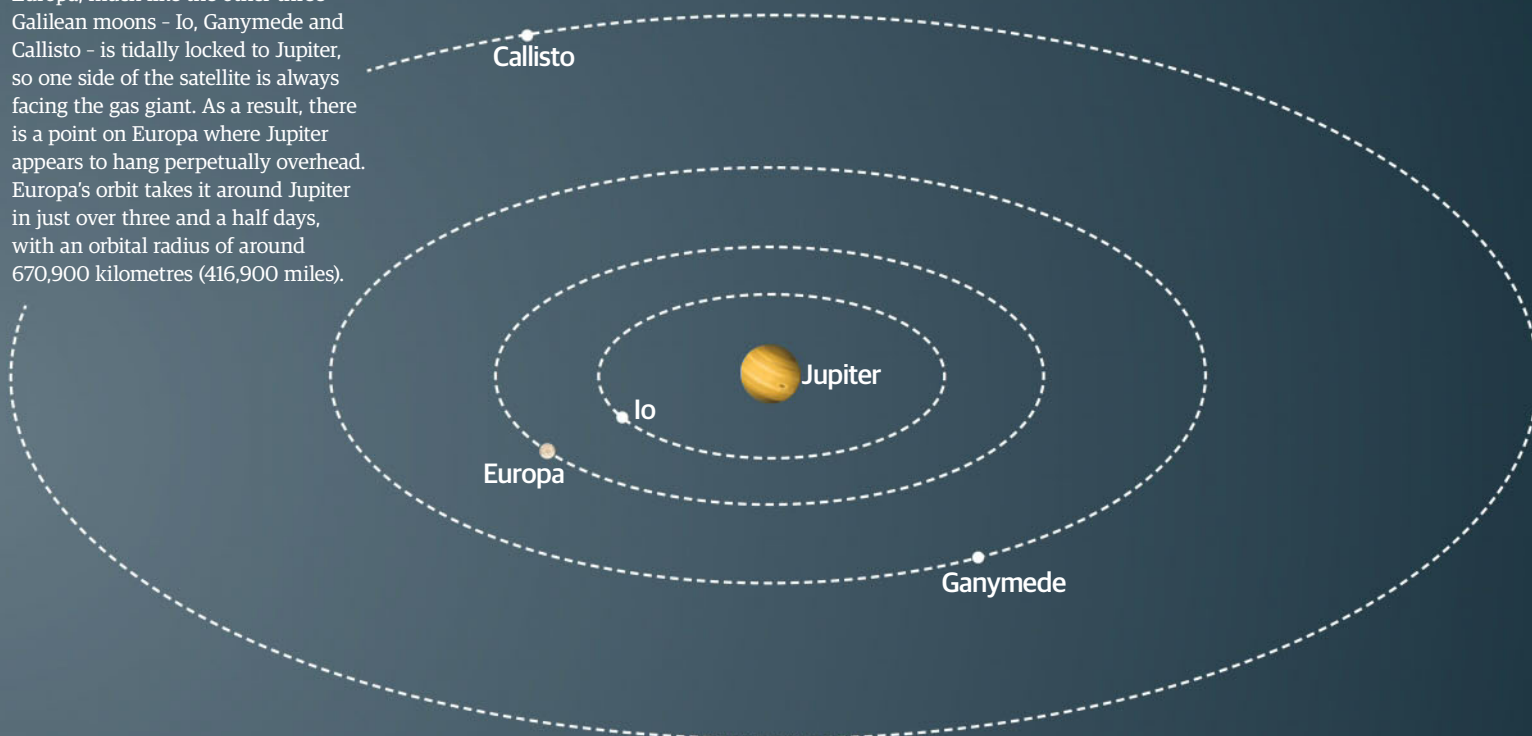


Europa in orbit

Europa, much like the other three Galilean moons - Io, Ganymede and Callisto - is tidally locked to Jupiter, so one side of the satellite is always facing the gas giant. As a result, there is a point on Europa where Jupiter appears to hang perpetually overhead. Europa's orbit takes it around Jupiter in just over three and a half days, with an orbital radius of around 670,900 kilometres (416,900 miles).

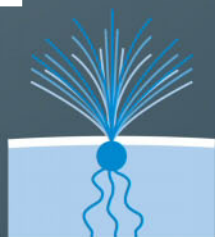
1 Europa year = 12 Earth years

1 Europa day = 3.5 Earth days



Europa in numbers

2013



The year the Hubble Space Telescope spied plumes of water vapour on Europa

3,100km

The diameter of Europa, which makes it slightly smaller than our Moon

4.5 billion

Europa's estimated age, making it roughly as old as Jupiter

45

The number of flybys planned by NASA for the Europa Clipper mission

0.64

The high light reflectivity of Europa - the highest of any moon in our Solar System

80km

The approximate thickness of the ice that covers the surface of Europa

Weather forecast

-160°C
-256°F



While we've only been able to image around 15 per cent of Europa's surface, studies of its atmosphere have revealed a few intriguing aspects. The temperature on the moon's surface is incredibly cold, averaging around -160 degrees Celsius (-256 degrees Fahrenheit) near the equator and plummeting to -220 degrees Celsius (-364 degrees Fahrenheit) near the poles.

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ALL YOU NEED TO KNOW ABOUT SPACE TIME

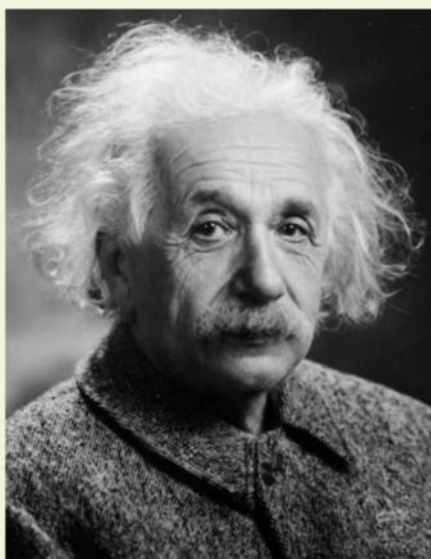
*Your cheat sheet to the
fabric of the cosmos*

Written by Colin Stuart

Just over 100 years ago, physicist Albert Einstein published a remarkable idea that turned many of our everyday notions about our existence on their heads. As we go about our daily lives, we consider space and time to be separate. We're relatively free to move about in space - you can get in a car, hop aboard a plane or jump on a rocket to outer space. Yet our movement through time appears a lot more restricted - it seems we can only go forwards and

the idea of changing the speed at which we travel through time seems very much like science fiction.

However, Albert Einstein's radical notion - published in his theories of special and general relativity - was that space and time are intimately interwoven into a single fabric that pervades the universe; what he called space-time. As we're about to see, this unique marriage has some very profound and unsettling consequences.

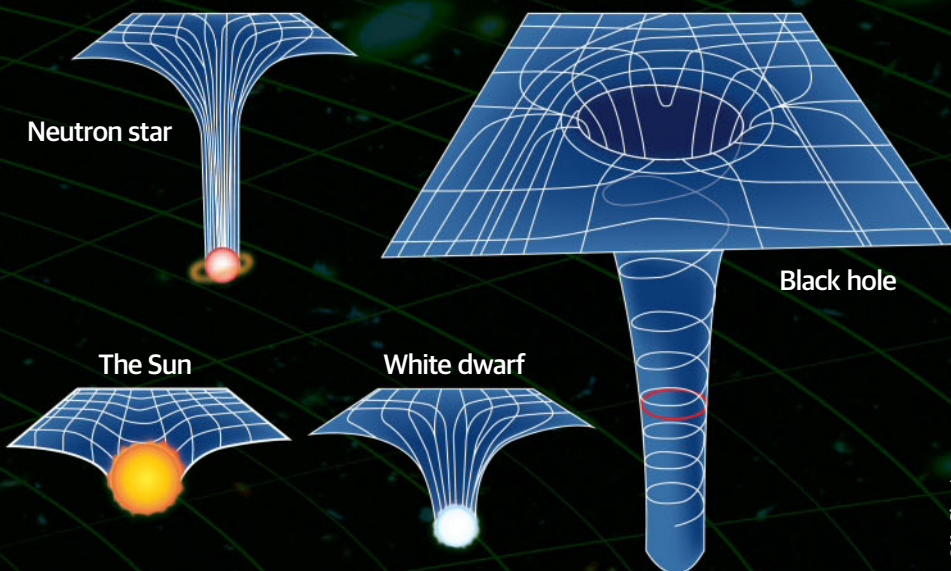


Albert Einstein

Born in Germany in March 1879, Albert Einstein developed the general theory of relativity, which serves as one of two pillars of modern physics alongside quantum mechanics. In popular culture, Einstein is best known for the world's most famous equation, $E=mc^2$, and he received the 1921 Nobel Prize in Physics for his services to theoretical physics.

Einstein's general theory of relativity was published in 1916, which explained that acceleration distorts the very shape of time and space. In other words, space and time are curved near a massive object. Some of his other important ideas were that the laws of physics are the same everywhere and that the speed of light is constant.

The heavier the object, the more space-time bends



In Isaac Newton's picture of gravity, the Earth and the planets orbit the Sun because our star exerts a gravitational pull on the worlds encircling it. But Einstein thought a little differently. He said that massive objects like the Sun bend the fabric of space-time around them.

An often-used analogy here is a bed sheet held tightly at each corner. If you placed a bowling ball in the centre to represent the Sun, then the sheet would dip in the middle. You could then roll a tennis ball around the rim of the dip and it would orbit around the bigger ball just as the Earth

orbits the Sun. The more massive the object, the more space-time is warped. The deeper the dip - which physicists call a 'gravitational potential well' - the faster you have to travel to escape it.

For the Earth it is about 11 kilometres (seven miles) per second. But extremely compact and massive objects such as black holes are so massive that, in order to climb out of the well, you'd have to travel faster than the speed of light, which, as we will see, is not possible. The space-time around a black hole is so warped that all paths lead back into it.

Shape of the universe



Flat universe

There is the right amount of mass to cause the expansion of the universe to stop, but only after an infinite amount of time. The universe will expand forever.

Open universe

In an open universe, the cosmos has no bounds and will expand forever because there is insufficient mass to slow it down to a standstill.

Closed universe

In a closed universe, there's more than enough mass to cause the expansion of the universe. In this case, the cosmos is not infinite but also has no end.

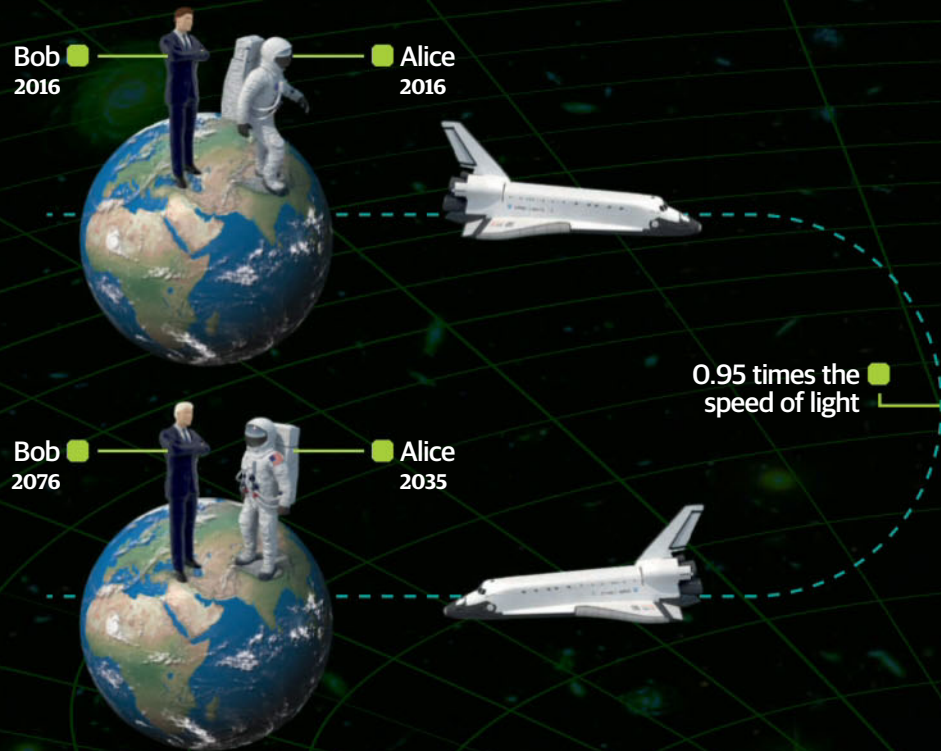
Space-time may be the fabric of the universe, but what is its overall shape? There are three possible options, which physicists refer to as open, closed and flat. An open universe would be shaped like a saddle, a closed universe like the surface of the Earth, and a flat universe like a sheet of paper. One way to tell is to measure the angles between three objects. At school we always learn that the angles of a triangle add up to 180 degrees, but that's only true on a sheet of paper. Draw a triangle between three cities on the surface of the Earth, for example, and the angles between them will add up to more than 180 degrees. On a saddle shape they will add up to less.

When astronomers perform these experiments, the answer they get is 180 degrees. So our universe appears to be flat. However, this might not be the whole picture. If you were restricted to a single town on Earth then you might think the Earth was flat - you don't notice its curvature over such a small distance. Likewise, our local universe might appear flat but the wider universe could be different.

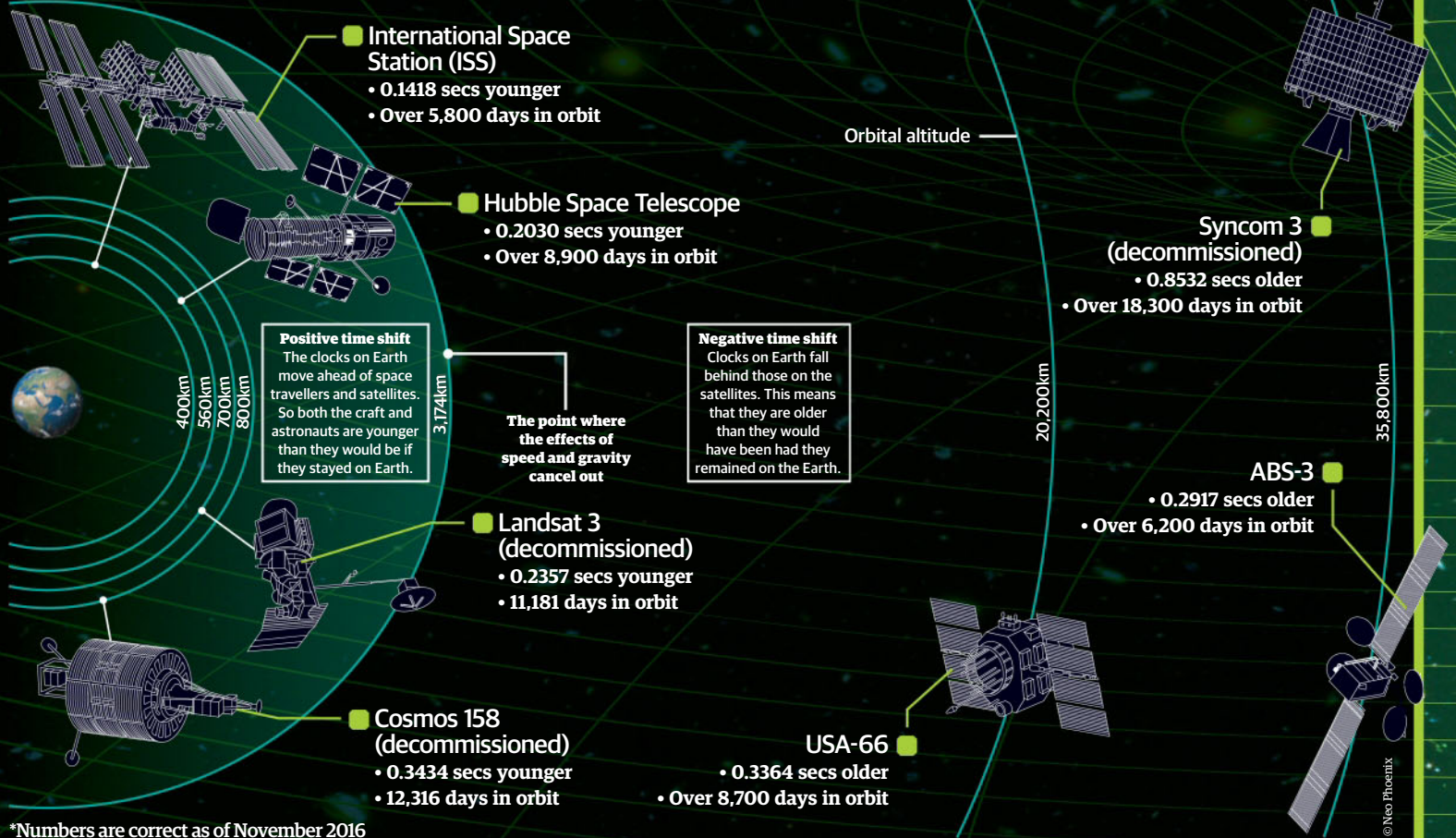
Moving clocks run slow

Back in 1905, Einstein predicted that moving clocks run slow relative to those that are stationary (or moving at a slower speed). But this has nothing to do with the mechanics of the clock - time itself is affected. Imagine twins Alice and Bob. Alice jumps on a rocket and travels around space at 95 per cent of the speed of light while Bob stays on Earth. Each twin feels time passing normally, but when Alice returns to Earth she'll realise that she is now much younger than her brother. That's because less time passed for her relative to her sibling. And that's all because she was travelling faster than him. The only reason we don't notice this day to day is that we never travel fast enough.

But this effect - known as time dilation - does play a fundamental role in our everyday lives. Take the fleet of GPS satellites orbiting around the Earth. They allow you to pinpoint your position on the surface of the Earth by exchanging time signals with your device. But those satellites are travelling at speed around the planet, moving faster than clocks on the ground. If the system didn't take into account time dilation then the whole system would be rendered useless very quickly.



Time dilation in orbit

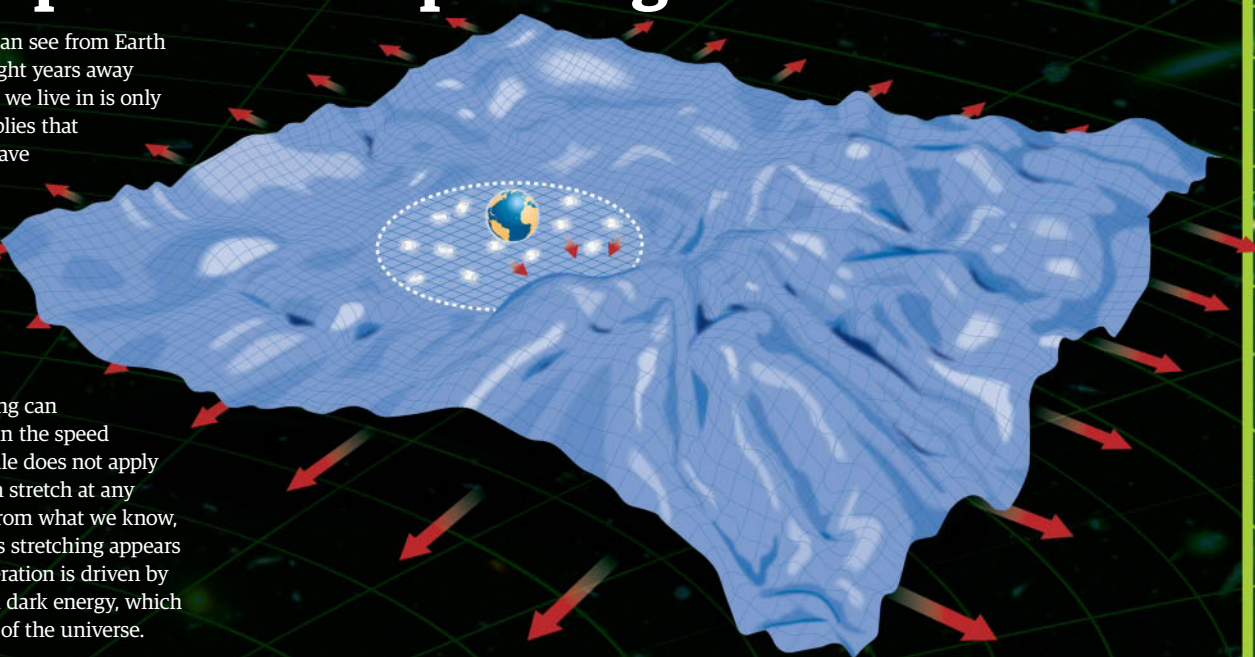


*Numbers are correct as of November 2016

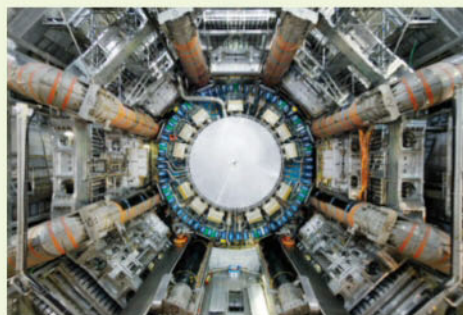
Fabric of space-time expanding with the universe

The furthest objects that we can see from Earth are now around 46.5 billion light years away from us. And yet the universe we live in is only 13.8 billion years old. This implies that the galaxies in our universe have been moving faster than the speed of light, in direct violation of Albert Einstein's cosmic speed limit. In truth, there is no such violation as it is not the galaxies themselves that are moving.

Einstein's rule is that nothing can travel *through* space faster than the speed of light. However, the same rule does not apply to space-time itself, which can stretch at any speed or rate it likes. In fact, from what we know, the rate at which space-time is stretching appears to be speeding up. This acceleration is driven by some mysterious entity called dark energy, which makes up around 68 per cent of the universe.



Moving objects gain mass...



Einstein also formulated what is probably the most famous equation in history: $E = mc^2$. It says that energy (E) and mass (m) are two sides of the same coin - they're interchangeable. Energy is mass and mass is energy and they are related by the speed of light (c). Any moving object has what physicists refer to as kinetic energy - the energy of movement. The faster you move, the more kinetic energy you have. But Einstein's equation tells us that energy is mass and so if your energy increases then so does your mass.

Any object gaining speed gains mass. And that includes you. A person with a rest mass of 70 kilograms, travelling on an airplane at 900 kilometres (559 miles) per hour would have a very slightly increased mass of 70.000000000002434 kilograms. However, particle physicists often have to deal with subatomic particles travelling at such speeds within particle accelerators, such as CERN. So you'll often hear physicists referring to a particle's 'rest mass' - the mass that it has when it is stationary.

... so matter cannot travel faster than light

As an object travels faster its mass increases. But if the object gets heavier then you need even more energy to make it go faster. Imagine you're wearing a backpack and running at a constant speed. If you accelerate, I put rocks in your bag. You then have to put in a lot more effort to accelerate again. And if you do, then I put even more rocks in your bag. Eventually the object becomes so heavy that an infinite amount of energy is required to accelerate it. This cut-off point is the speed of light and is why any object with mass cannot travel at the speed of light.

Particles of light - which Einstein called photons - can travel at the speed of light because they have no mass. That said, it is technically possible for an object with mass to travel faster than the speed of light, but it must have *always* been travelling that fast. It cannot start out moving slower than the speed of light and then accelerate to faster than the speed of light. Such hypothetical particles are called tachyons.



Frame of reference

Einstein wasn't the first person to introduce a theory of relativity. In the 17th century, Galileo Galilei said that it is impossible to conduct an experiment to tell the difference between being stationary and moving at a constant speed. Most of us have been in a similar situation in a car or on a train. At first you think you're moving, but then realise that it's the other vehicle moving. But if you cannot see the outside you have no way of testing if you are moving.

If you're stationary or moving at a constant speed then you are said to be in an 'inertial reference frame', something which plays a key part in Einstein's theories of relativity. His revelations about time dilation and length contraction came from two very simple starting points. First, that the speed of light is the same for all observers. Second, that the laws of physics are the same in all inertial reference frames.

Moving objects appear shorter

A related phenomenon to time dilation is length contraction. An object moving at high speed relative to a stationary observer will appear to be shorter along the direction of motion than it would be at rest. Again, we don't notice this effect in our everyday lives because the effect only kicks in significantly at high speed. An object measuring 200 metres (656 foot) long at rest will be measured by a stationary observer as 199 metres (653 foot) long if it is travelling at ten per cent the speed of light.

Putting length contraction and time dilation together helped to explain a mystery surrounding muons – subatomic particles that are created high up in the Earth's atmosphere. These particles split into other particles very quickly, meaning that very few muons should ever make it to the ground. However, a number of experiments have found that many muons do complete the journey to Earth's surface.

From our point of view here on Earth, the muon experiences time dilation and so, not thinking as much time has passed, doesn't have the time to split into other particles. From the muon's point of view, it sees the distance to the ground length contracted and so can make it the short distance to Earth in the little time that it has before breaking up.

Stationary

0.20 times the speed of light

0.40 times the speed of light

0.59 times the speed of light

0.79 times the speed of light

0.99 times the speed of light



Gravity bends light

Einstein's picture of curved space-time explains why light can appear to be bent by massive objects even though light is massless. A beam of light will follow the local curvature of the space-time in which it is moving through. In fact, the bending of light was a crucial test that helped champion Einstein's ideas. In 1919 there was a solar eclipse, which allowed astronomers to see some of the stars close to the Sun in the sky. These stars appeared in a slightly different position from usual as their light was bent by the Sun.

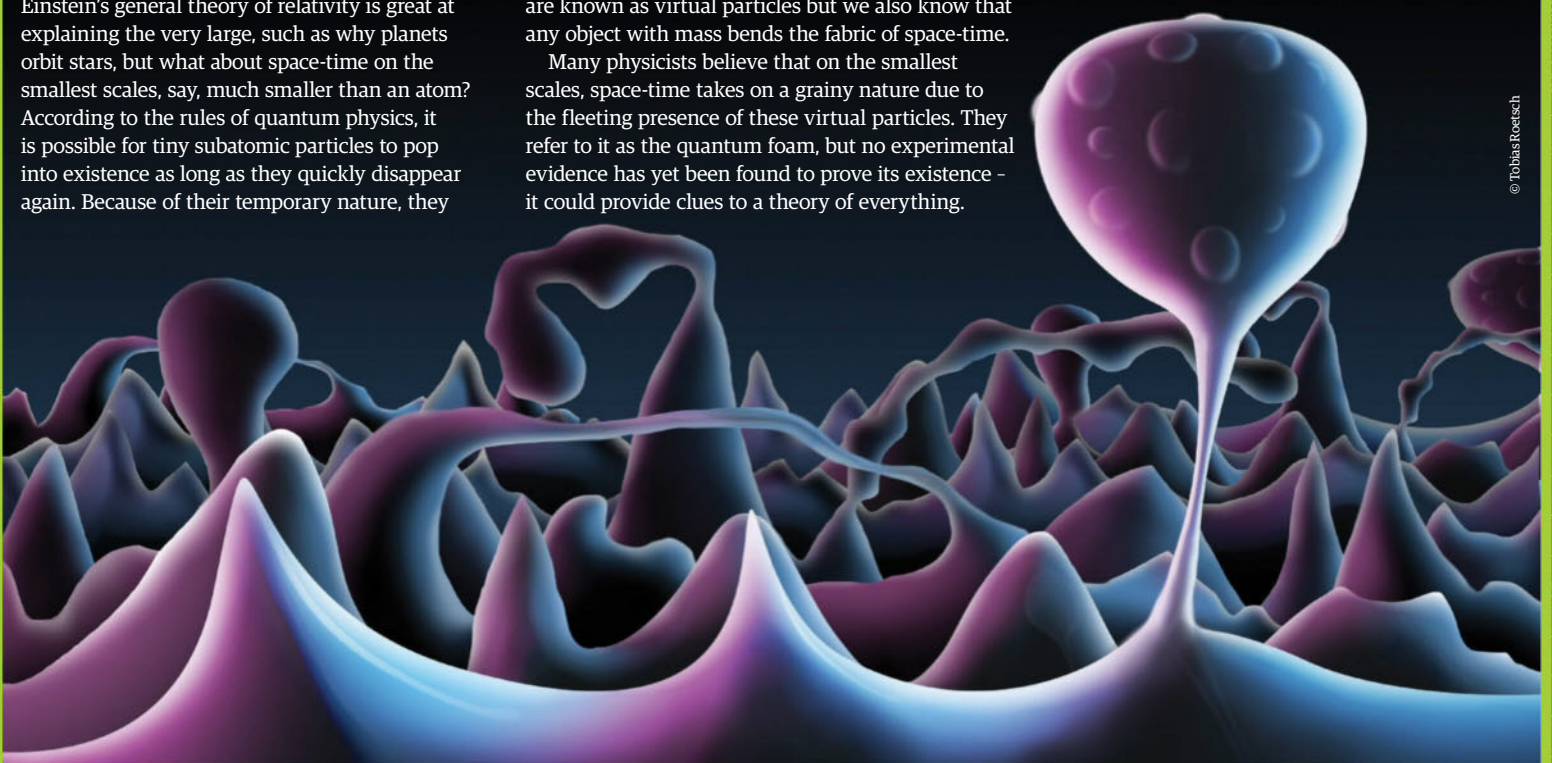
Both Newton and Einstein's ideas predicted this, but differed on how much the light would bend. Photographs of the 1919 eclipse showed that Einstein was right and his ideas of space-time were vindicated. Light from a distant object can even be bent around a galaxy cluster, forming arcs of light or Einstein rings.

Quantum foam

Einstein's general theory of relativity is great at explaining the very large, such as why planets orbit stars, but what about space-time on the smallest scales, say, much smaller than an atom? According to the rules of quantum physics, it is possible for tiny subatomic particles to pop into existence as long as they quickly disappear again. Because of their temporary nature, they

are known as virtual particles but we also know that any object with mass bends the fabric of space-time.

Many physicists believe that on the smallest scales, space-time takes on a grainy nature due to the fleeting presence of these virtual particles. They refer to it as the quantum foam, but no experimental evidence has yet been found to prove its existence – it could provide clues to a theory of everything.

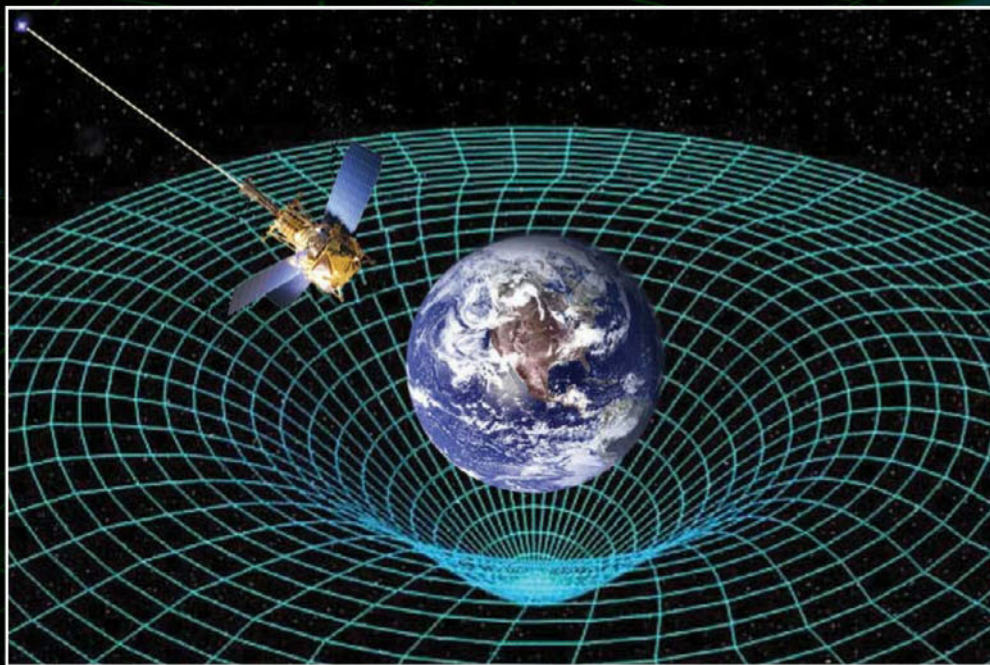


© Tobias Roetsch

Frame-dragging

It is rare for a massive object in space to be completely stationary. Often they are rotating on the spot just like the Sun or the Earth. And as the object rotates it drags space-time around with it - an effect known as 'frame-dragging'. As a result, any object in orbit around the body will also get shifted slightly in its orbit. The effect was first predicted by Einstein in his theory of general relativity but wasn't confirmed until 2004, when astronomers showed that two spacecraft in orbit around the Earth had shifted their orbit by two metres (6.6 feet). In 2011, NASA's Gravity Probe B provided an even more accurate measurement.

This effect is likely to be more pronounced near a rotating black hole - often referred to as a Kerr black hole by astronomers. Monitoring the orbits of stars around the black hole at the centre of the Milky Way could provide additional evidence of frame-dragging. Some black holes in other galaxies are particularly active, devouring material and producing jets of radiation. New telescopes will soon be able to study the base of these jets, potentially finding further evidence of frame-dragging in the process.



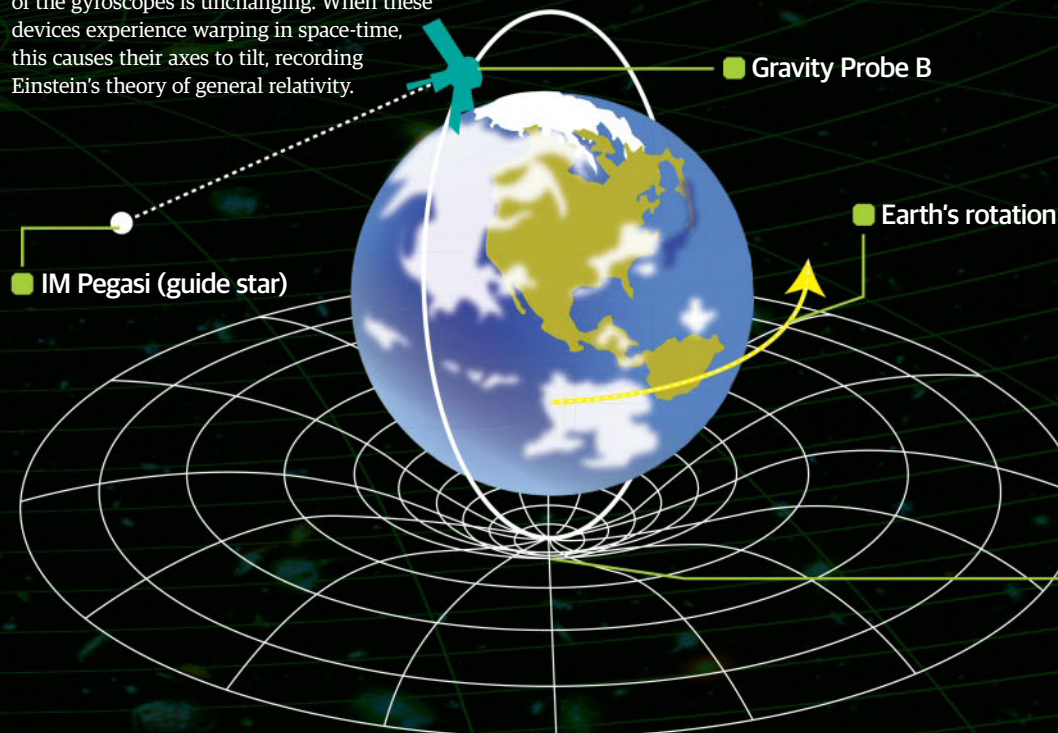
The experiment

Back in 2004, NASA's Gravity Probe B satellite launched into Earth orbit to test two predictions of general relativity. Trained on guide star IM Pegasi, a binary star system in the constellation Pegasus, the satellite is in constant alignment throughout its polar orbit, meaning that the spin of the gyroscopes is unchanging. When these devices experience warping in space-time, this causes their axes to tilt, recording Einstein's theory of general relativity.



The gyroscopes

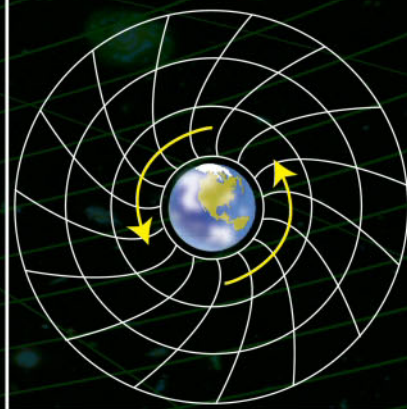
Small enough to fit into the palm of your hand, the table-tennis-ball-sized gyroscopes are the most perfectly formed spheres ever made for optimum accuracy.



The results

FRAME-DRAGGING

According to relativity, large objects such as the Earth move or rotate. As this happens, they drag space-time around with them. This has been confirmed by Gravity Probe B.



Space-time distortion

The gyroscopes' angle is changed by 0.0018 degrees per year, due to Earth's gravity causing a distortion in the fabric of the universe. Another prediction of general relativity - the geodetic effect - has been confirmed.

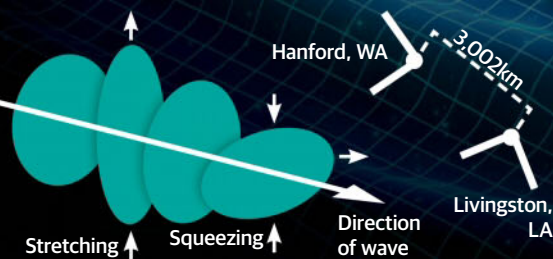
Space-time wrinkles and crinkles with events in the universe

One of the implications of Einstein's work is that violent events in the universe should produce distortions in the fabric of space-time. Imagine space-time as the surface of a pond and that two black holes collide somewhere in the universe. If general relativity is correct, this immense collision should send ripples across the surface, known as 'gravitational waves'. Recently, the Advanced LIGO experiment in the US detected gravitational waves from colliding black holes for the first time; further vindicating Einstein's ideas.

The detector consists of two four-kilometre (2.5-mile) long tracks at right angles to each other. Lasers are fired down each track and bounce off a mirror at the end. All things being equal, both laser beams should return to the start at the same time because the tracks are of equal length. However, if a gravitational wave has passed through, then the space-time inside the detector will have temporarily been distorted, meaning the length of one of the tracks is slightly different. This means the laser beams return to the start at slightly different times.

Light speed

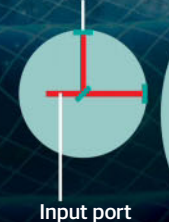
The waves race through space at the speed of light, stretching space in one direction and squeezing it in another.



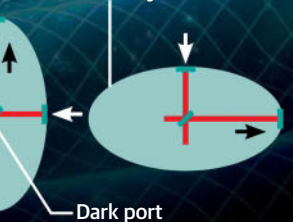
Bouncing light

In the 4km (2.5mi) arms of the LIGO interferometer, light bounces back and forth. When one of these ripples makes the arms unequal in length, light leaks out of the 'dark port' to reveal the wave.

No distortion



Distorted by waves



Catching a wave

The LIGO experiment detected waves that were created by two black holes spiralling together, which radiated ripples in space-time, known as gravitational waves. These ripples have a wavelength that's roughly equal to the distance between LIGO's detectors in Hanford, Washington and Livingston, Louisiana.



Space-time inside black holes

What's at the centre of a black hole? It is a question that is intriguing and very hard to answer. Following Einstein's general theory of relativity, the rules suggest that all the in-falling matter is squashed down into an infinitely small, infinitely dense point called a singularity. Here, both space and time end. But that is unlikely to be an accurate picture because it ignores the rules of quantum physics.

So what we really need is a theory of quantum gravity - one that combines general relativity and quantum physics. But when physicists try and get the theories to play nicely together, the equations stop working. The only way they can get it to work is if the universe has 11 dimensions rather than the four that are traditionally associated with space-time. If they do exist, these extra dimensions must be curled up really small so as to remain out of sight.



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GROUNDBREAKING SPACE IMAGES

Astronomical images often dazzle us, but their primary purpose is to help us understand our universe

Written by Kulvinder Singh Chadha

Galaxy Cluster Abell S1063

Taken by: Hubble Space Telescope

Year taken: 2016

Importance: A spectacular example of gravitational lensing

The Hubble Deep Fields Initiative 2012 (or the Frontier Fields programme) was a plan to study galaxies in the early universe using gravitational lensing. This was predicted by Einstein's theory of general relativity, which states that what we consider as gravity is the warping of the fabric of space-time caused by mass. The Frontier Fields programme used gravitational lensing as a means to focus light from distant early galaxies, making them easier to observe. But the level of gravitational lensing required called for colossal amounts of mass. Luckily, galaxy clusters contain the requisite amount of mass, much of it in the form of dark matter - a mysterious, invisible substance that comprises 84.5 per cent of the universe's mass and is only detectable gravitationally.

Abell S1063, seen in the centre of this image and lying 4 billion light years away, is one such cluster. It contains 100 million million solar masses, mostly in the form of dark matter. Although that makes studying dark matter very challenging (to date, it's nature is still unknown), this is advantageous for gravitational lensing studies. Arcs from distant galaxies would otherwise be swamped by light or radiation from normal matter. The blue arcs seen here are distant galaxies approximately 4 billion years further behind Abell S1063!



Deepest look into the universe

Taken by: Hubble Space Telescope

Year taken: 2002-2009

Importance: Deepest view of the universe to date

In 1995, the Hubble Deep Field (HDF) image revealed nearly 3,000 galaxies stretching across 12 billion light years, all within an area that is one 24-millionth of the whole sky. That image was instrumental in showing the true expanse of galaxies in the universe. But the eXtreme Deep Field (XDF) image that you can see here is effectively a decade in the making.

This XDF image combines visible and infrared images from the Hubble Ultra Deep Field - a follow-up to HDF taken in 2002, 2003 and 2009. Each side of this image is 2.4 arcminutes in size, similar to the original HDF. It contains 5,500 galaxies and covers a small area of space in the constellation Fornax. The oldest galaxy in this image is 13.2 billion years old, when the universe was five per cent of its current age. So to date, the XDF represents the deepest-ever view into our universe.



Saturn's polar vortex

Taken by: NASA's Cassini spacecraft
Year taken: 2012

Importance: First view of Saturn's northern polar vortex

NASA's Cassini spacecraft has been observing Saturn intently since 2004. In that time it has observed Saturn's many natural satellites, planetary bands, the most intense storm ever seen on Saturn (still occurring at the time of writing)

and a hexagonal polar vortex. When Cassini arrived at Saturn in 2004, the north pole was in darkness. But in 2012 the northern winter began to break, revealing something unusual.

This false-colour image shows Saturn's northern polar vortex looking like a turbulent, swirling rose. Green areas show high clouds and red areas show lower clouds. This structure is a polar hurricane -

the eye of which is 2,000 kilometres (1,250 miles) wide. For comparison, an average hurricane on Earth is 50-times smaller than this vortex. The speed of the hurricane's outer clouds is over 540 kilometres (335 miles) per hour. On Earth, hurricanes are driven by warm ocean water, but the driver for Saturn's hurricane is still a mystery and will be closely studied.



The first picture of Earth

Taken by: Astronaut William Anders

Year taken: 1968

Importance: First full-frame image

A sight to behold: the first full-frame image of our planet taken by humans from space. It was taken by one of the crew of Apollo 8, the first manned mission to orbit the Moon. The north of this image is at the bottom, and it is in darkness as it's night-time there. The south is at the top but is just disappearing behind the horizon.

South America is clearly visible - but covered by clouds. The continent's southern tip disappears over the horizon, meaning that Antarctica, sadly, isn't visible. To the lower left of South America is part of Western Africa - with the rest of the continent in darkness. At the time, Apollo 8 was the furthest distance that humans had travelled from Earth, and this image was taken from 30,000 kilometres (18,640 miles) away!

The surface of a comet

Taken by: ESA's Rosetta spacecraft and Philae lander

Year taken: 2014-2015

Importance: First lander on comet and first images from Comet 67/P

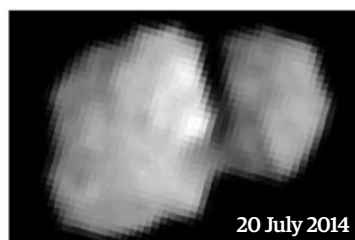
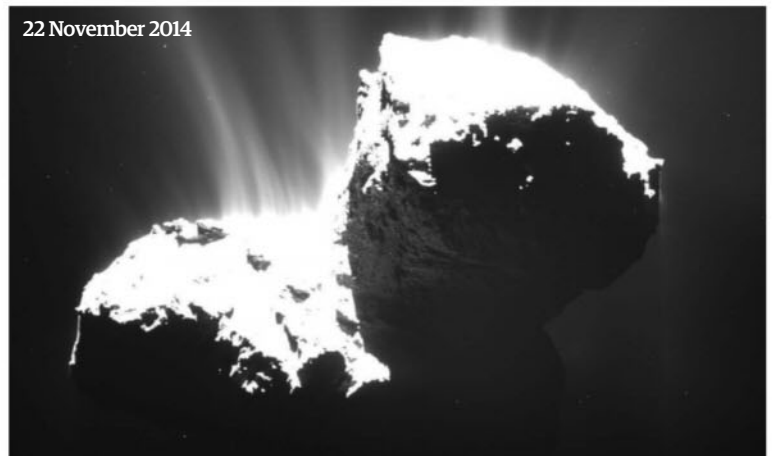
At first, this black and white image resembles Jack Nance's famous picture from the film *Eraserhead*. But this is actually one of the Rosetta spacecraft's first images of its primary destination: Comet 67P/Churyumov-Gerasimenko. Despite being a comet, the object - described as looking like a 'rubber duck' - actually originates from the Asteroid Belt.

The largest part is approximately 4.1 x 3.3 x 1.8 kilometres (2.5 x 2.1 x 1.1 miles) in size, with the 'duck's head' being 2.6 x 2.3 x 1.8 kilometres (1.6 x 1.4 x 1.1 miles) in size. There are earlier images of 67P from Rosetta's Optical, Spectroscopic, and Infrared Remote

Imaging System (OSIRIS), such as the one shown bottom left; but they're of much poorer quality, as the spacecraft was much further away. The main image, taken six months later and at a smaller distance, reveals wispy jets emanating from the comet, but the exact physical processes that create them are still being investigated. Rosetta took its last image on 3 October 2016, but the work on the data it collected will continue.

The same could be said for Philae, which was the first craft to ever land on a comet. The image on the bottom right was taken on 12 November 2014 by Philae's Rosetta Lander Imaging System (ROLIS) when it had just 38.6 metres (126.6 foot) to go until it reached the Agilkia landing site on Comet 67P. Dust, debris and a large boulder can be seen.

22 November 2014



20 July 2014



12 November 2014



Detailed image of Andromeda

Taken by: Hubble Space Telescope

Year taken: 2010-2013

Importance: Most detailed image of another galaxy

This is the most detailed picture ever created of our closest galactic neighbour - or any galaxy other than ours, for that matter. It took the Panchromatic Hubble Andromeda Treasury team 7,398 individual exposures to image just this portion of Andromeda, which they then stitched together.

Despite Andromeda being 2.5 million light years away, 117 million individual stars and star clusters can be seen in this 61,000-light-

year-wide image. The help of myriad citizen scientists was crucial in making an accurate count of so many stars. This is because, by calculating the percentage of stars with particular masses in a cluster, scientists can make accurate assessments of Andromeda's 'Initial Mass Function'. This tells us how stellar masses are distributed within a galaxy and ultimately provides clues to the formation of the universe. This single mosaic alone represents 3.25 years of exposures and would be 220 x 78 centimetres (87 x 31 inches) in size if printed out at full print resolution.

Map of the Milky Way

Taken by: ESA's Gaia spacecraft

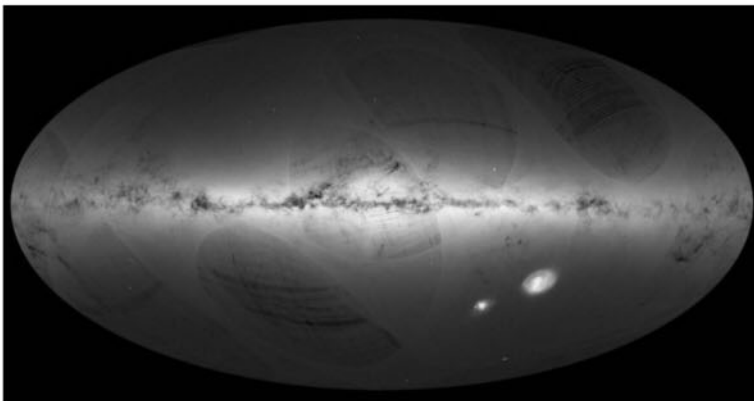
Year taken: 2014-2015

Importance: Most detailed, 3D, billion-star map of our galaxy

This picture really can't do justice to what ESA's Gaia craft has achieved. Contained within this all-sky view of the Milky Way are no fewer than 1.142 billion individual stars. Each one has been catalogued with a precision of between 0.5 and 15 milliarcseconds (a milliarcsecond being equivalent to the diameter of a UK five pence piece

from 5,800 kilometres, or 3,600 miles, away). In order to map all of these stars, Gaia had to image 50 million per day, carrying out ten separate measurements on each.

Surprisingly, that works out to a total imaging time of 22.84 days. This impressive feat occurred thanks to Gaia's 106 CCDs, making it effectively a gigapixel camera. Cataloguing the Milky Way in such detail is important as it allows us to see how objects such as stars and quasars are distributed.



First image of an exoplanet

Taken by: Very Large Telescope

Year taken: 2005

Importance: Our first direct shot of an exoplanet

The brown dwarf 2M1207 and its companion 2M1207b may at first seem like an unassuming pair, but this composite image is something special.



Taken by: Visible and Infrared Survey Telescope for Astronomy

Year taken: 2016

Importance: Reveals hidden stars in a well-known nebula

These colourful 'blobs' are reflection nebulae, some 1,600 light years away in the constellation of Orion. On the right is Messier 78, and on the left is NGC 2071. Cosmic dust in both nebulae scatters and reflects light from hot, blue, young stars within. This image was taken with ESO's Visible and Infrared

Survey Telescope for Astronomy (VISTA) and shows dark bands of cold dust obscuring the scattered light behind. These colder, thicker bands are likely sites for future star formation. The stars shining within these nebulae would normally be obscured, but VISTA can see through the thinner regions of dust in order to reveal them.

Some of these, although bright, don't yet have cores hot enough for nuclear reactions to take place. But in a few tens of millions of years, they will become 'true' stars.

This pair of objects were discovered in April 2004, around 170 light years from Earth. The red object, 2M1207b, is six-to-ten times as massive as Jupiter, meaning that it is a planet - albeit a massive one. That makes 2M1207b the first exoplanet (a planet in a Solar System beyond our own) to have been directly imaged. Using the European Southern Observatory's ground-based telescopes in Paranal, Chile, astronomers saw 2M1207b as

a speck 100-times fainter than the brighter blue-white brown dwarf.

At first, it was thought that the smaller object was an optical artefact, until follow-up observations were made by Hubble - the objects were moving together, so these two objects were gravitationally bound. The planet is 55-times further from the brown dwarf than Earth is from the Sun. This makes the objects a little further apart than Pluto is from the Sun at aphelion.

Close-up of Pluto

Taken by: NASA's New Horizons

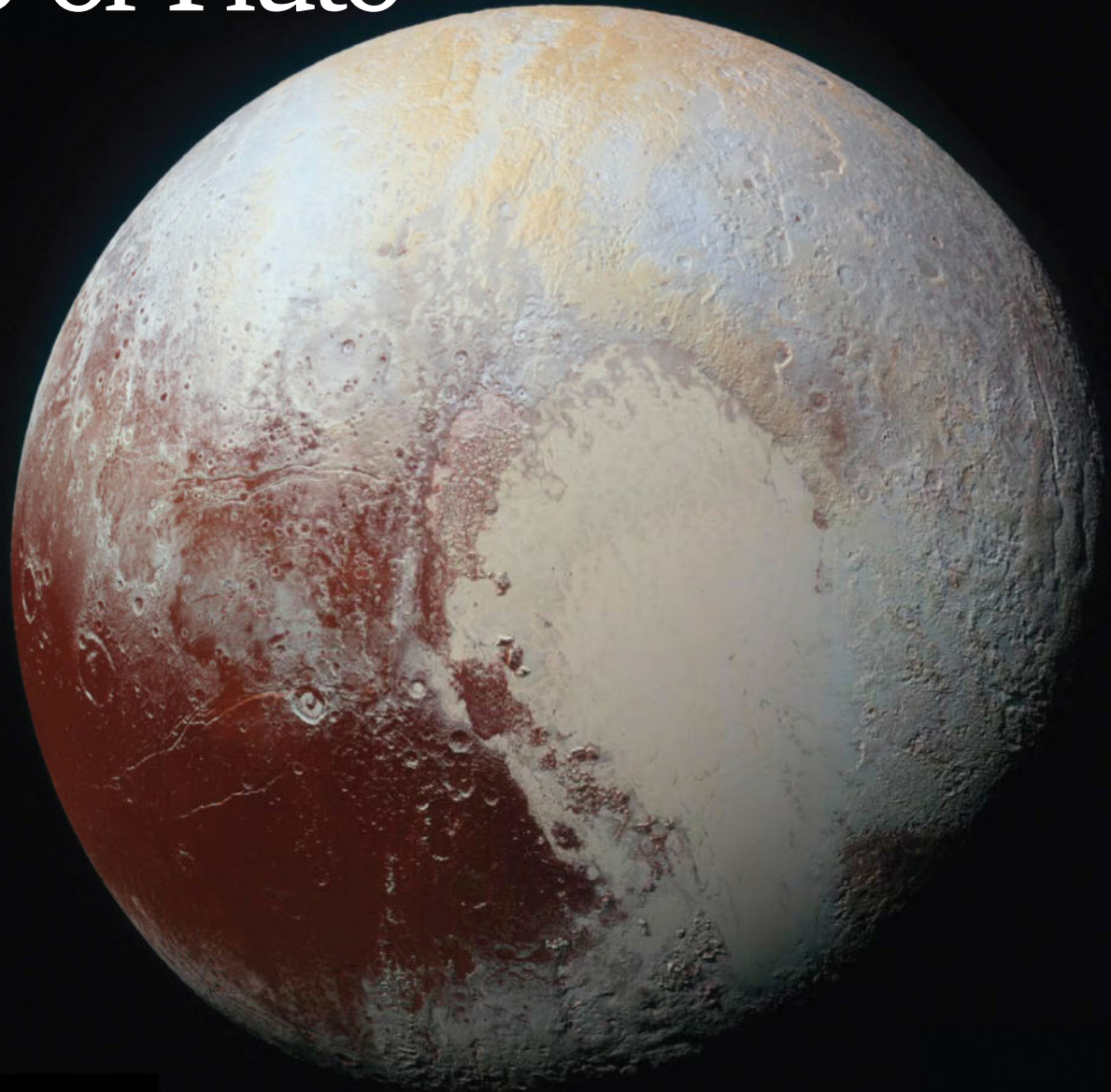
Year taken: 2015

Importance: First close-up image of dwarf planet Pluto

New Horizons' full-disc image of Pluto is probably the most important picture from our Solar System this century. For years, this small and unassuming icy-rocky world was a near-total mystery to us. Up to that point, the most detailed images we had of Pluto were those taken by Hubble between 2000 and 2002. But all they could reveal were fuzzy grey and brown patches.

Pluto was the last major planet – and the smallest at just 1,187 kilometres (738 miles) in diameter – to be visited by a space probe. That all changed when Stamatios Krimigis of Johns Hopkins University's Applied Physics Laboratory, and Alan Stern of the Southwest Research Institute, submitted their 'New Horizons' proposal to NASA as part of its New Frontiers programme. The proposal was a success and the probe was built and launched in 2006. The fact that the International Astronomical Union changed Pluto's classification from a major planet to a 'dwarf planet' wouldn't deter them. Nearly ten years later, New Horizons showed Pluto in exquisite detail for the first time ever.

This enhanced-colour image, taken from 450,000 kilometres (280,000 miles) away, shows different types of terrain, including a distinctive, pale, 'heart-shaped' region called Tombaugh (after Pluto's discoverer).



Pluto's atmosphere in twilight

Taken by: NASA's New Horizons probe

Year taken: 2015

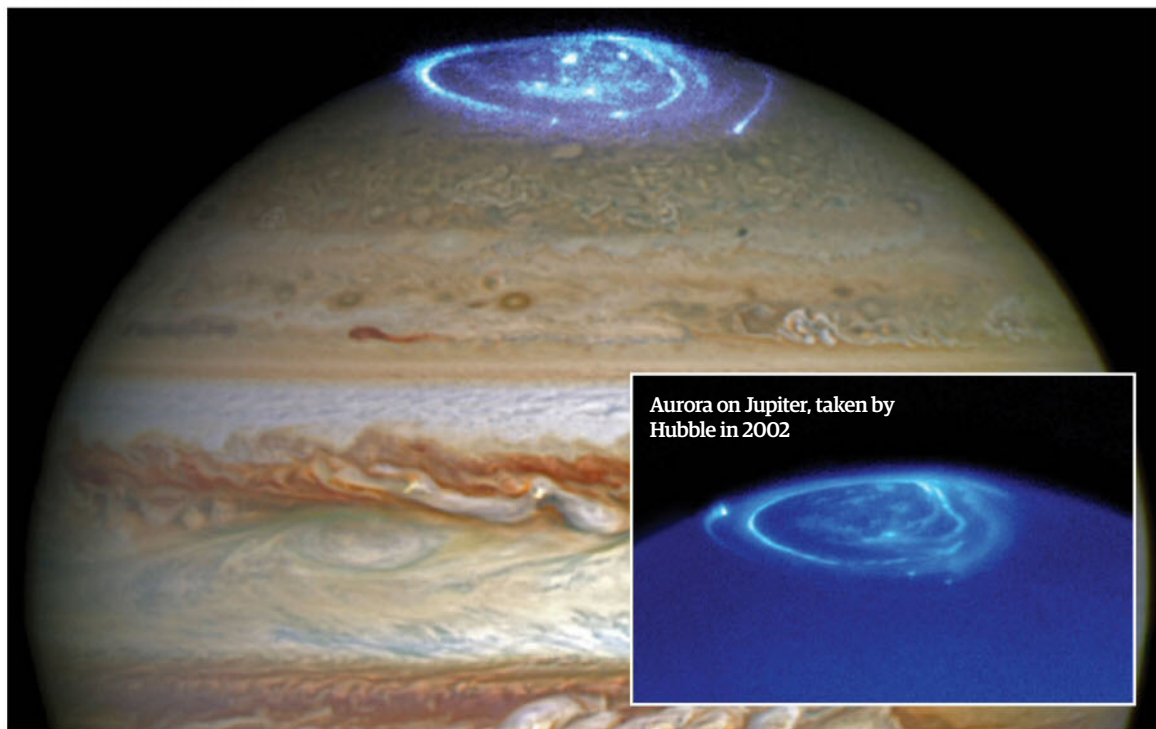
Importance: First detailed view of Pluto's atmosphere

Just after its closest approach, New Horizons took this eerie image of Pluto's atmosphere. The image shows atmospheric haze layering over the dwarf planet with light from the distant Sun filtering through. The probe's scientists have identified around 20 haze layers, with the atmosphere rising 200 kilometres (124 miles) above the surface.

Pluto's atmosphere consists mostly of nitrogen, with some methane and carbon monoxide present too. These

gases sublime from the surface to form Pluto's atmosphere, which is 100,000 to 1 million-times thinner than Earth's, according to the craft.

This image also amazingly shows Pluto's true colour. Pluto's haze is a photochemical smog resulting from sunlight acting on methane and other molecules to produce a hydrocarbon mixture (such as acetylene and ethylene). These form small particles to scatter sunlight and create the blue colour you can see. Such a dramatic image of Pluto gives scientists data they couldn't have collected if the craft were viewing the dwarf planet with the Sun shining face-on (as above).



Aurorae on another planet

Taken by: Hubble Space Telescope
Year taken: 2016 (first taken in 1992)
Importance: Gives an insight into Jupiter's magnetic field

In 1992, Hubble spotted an aurora on a planet other than Earth for the first time: Jupiter. This image, taken in 2016, reveals the stunning light display on the planet's north pole. On Earth, aurorae happen when high-speed charged particles of the solar wind collide with other charged particles already trapped in our magnetosphere. Depending on the actual atomic

excitation method and altitude, Earth's aurorae can come in a range of colours, from red, green, pink, yellow, blue and even infrared and ultraviolet. As aurorae occur where Earth's magnetic field is strongest, they are most prominent in the polar regions.

Jupiter's aurorae are ultraviolet. This image was taken with Hubble's Imaging Spectrograph and shows electrons from the solar wind colliding with particles in Jupiter's upper atmosphere, after becoming trapped by its magnetic field. This is very

similar to how Earth's aurorae form. But Jupiter is a gas giant with strong radiation belts and a magnetic field of 4.3 Gauss - 20,000 times more powerful than ours.

This image also shows auroral 'footprints' from Jupiter's moons. Io's is the bright, 'comet-like' feature on the left, while Ganymede's is the dot outside the oval and a little to the right. Europa's is the dot close to that on the lower right. These are unlike anything on Earth and show electric currents from the moons to the planet.



'Jigsaw piece' of our galaxy

Taken by: Very Large Telescope
Year taken: 2016
Importance: Reveals secrets of early galaxy's history

Within the dense, central bulge of our Milky Way lies the star cluster Terzan 5. Star clusters of all kinds are myriad - not just in our galaxy but in others, too. But Terzan 5 appears to be composed of two distinct groups of stars, which differ in age by 7 billion years. This is peculiar for a cluster, as stars within tend to form at around the same time. Terzan 5 seems to have undergone two separate bursts of star formation, meaning it would have had to be 100 million solar masses. This makes Terzan 5 an ideal 'testing ground' for galaxy formation theories, which state that vast clumps of stars and gas interacted to form our galaxy's central bulge. "Such 'galactic fossils' allow us to reconstruct the history of our Milky Way," says Francesco Ferraro of the University of Bologna, Italy.



Strange dunes on Mars

Taken by: NASA's Mars Curiosity Rover
Year taken: 2015
Importance: Type of sand dune not seen on Earth

Both Earth and Mars have large sand dunes up to 100 metres (330 foot) in size, as well as smaller 'ripples'. On Earth these ripples show up as corrugations on dunes and beaches, less than 30 centimetres (12 inches) apart, and are caused by wind-carried sand grains colliding.

But Mars also has sand structures with crests around three metres (ten feet) apart - only seen on Earth with underwater sediment. So what's the cause of these metre-scale structures

on Mars - which is a desert world? For years, scientists thought that these were 'impact ripples', like Earth's smaller ones. But when the Curiosity rover approached Bagnold Crater, not only did it see the expected corrugations of smaller ripples, but mid-sized ripples that looked like ocean waves. Mathieu Lapôtre of Caltech is a collaborator on the Curiosity mission. He and his coauthors conclude that the ripples form by Martian wind dragging sand particles the way that flowing water drags sediment on Earth. "The size of the preserved [metre-scale] ripples may have recorded the thinning of the atmosphere," says Lapôtre.

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A person is seen from behind, standing inside a large, dark geodesic dome. The dome's structure is a network of dark lines forming triangular panels. Through the panels, a bright orange and yellow sunset or sunrise is visible over a vast, flat, reddish-brown landscape, likely representing Mars. The person's hair is slightly blowing in the air.

SpaceX's plan to colonise Mars

The CEO of private space company SpaceX, Elon Musk, has outlined his ambitious plans to send 1 million people to the Red Planet - using a so-called Interplanetary Transport System

Written by David Crookes

There are many questions about space, but one in particular has intrigued humankind for some time. Is there life on Mars? We still don't have a definitive answer but if plans put forward by Elon Musk come to fruition then, at some point in the near future, there certainly will be: us, or at the very least, those of us who can afford it.

Musk is the founder of SpaceX and he has now gone into more detail about his ambitious proposal to populate the Red Planet. Speaking at the International Astronautical Congress conference in Mexico, he expressed hope that anyone able to muster up \$200,000 (around £163,000) would soon be able to climb aboard one of his proposed

spaceships and go on humankind's boldest and bravest adventure yet.

The aim for the first human Martians would be to build a sustainable civilisation, as a way of future-proofing life ahead of the inevitable extinction event that will one day wipe all of us out. But while that's expected to be millions of years in the future, Musk reckons we ought to be acting now, laying the foundations for survival and making humans a multi-planetary species.

In order to achieve his aim, Musk has considered other celestial bodies in the Solar System, from the moons around Jupiter and Saturn to our very own natural satellite. But Mars wins out every time. "It's

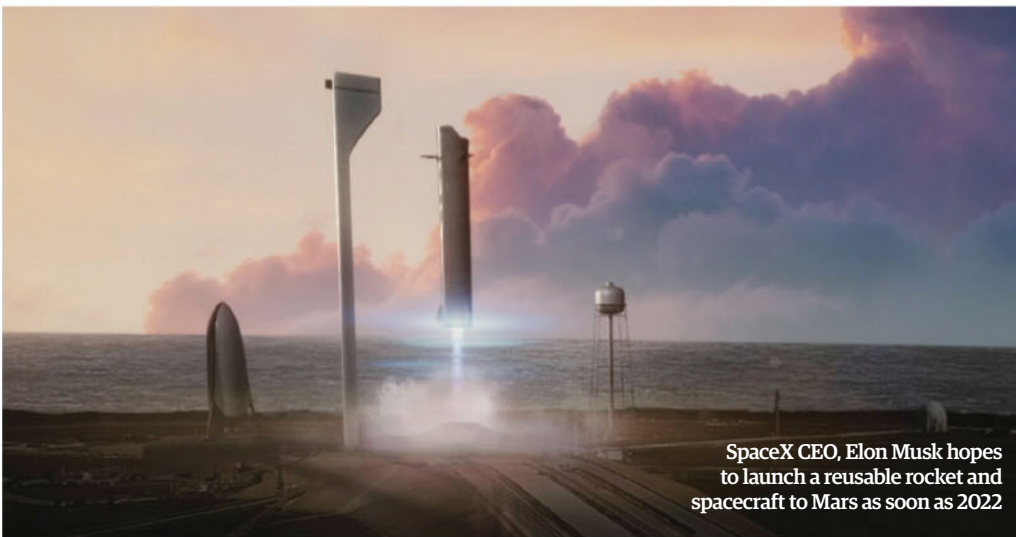
challenging to become multi-planetary on the Moon because it's much smaller than a planet, it doesn't have any atmosphere and it's not as resource rich as Mars," explains Musk. "It's got a 28-day long day while a Mars day is 24-and-a-half hours and, in general, Mars is suited to ultimately scale up to be a self-sustaining civilisation."

It won't be easy since a fair few steps are needed to make Mars habitable, least of all the artificial warming of the planet to allow the atmosphere to thicken and liquid oceans to flow once more. Yet Musk points out that Mars gets "decent sunlight", since it's half-a-day as far from the Sun as the Earth, and that plants could be grown by compressing the atmosphere. Besides, his immediate aim is working out the best, safest and most inexpensive method of transportation to get people there. The rest, he says, can be worked out later.

So how is he looking to do it? Musk hopes to eventually build as many as 1,000 huge, reusable spaceships, each carrying 100 passengers, their luggage and tons upon tons of cargo. They would set off during the launch window for Mars, which comes round every 26 months, and they would travel at around 100,800 kilometres (62,634 miles) per hour on a journey that could take as little as 80 days. But although Musk conceded that only a relatively small number of people will actually want to go, what is perhaps more remarkable is the mooted timescale. "What I really want to try and achieve here is to make Mars seem possible - like something we can achieve in our lifetimes," says Musk. He hopes flights will start as soon as 2022 and he says passengers would need just a day or two of training.

While that may sound jaw dropping, over-confident and perhaps even delusional, if anyone can do it then maybe Musk can. Since setting up SpaceX in 2002, the company has launched the first privately-funded, liquid-propellant rocket, known as Falcon 1, into orbit; launched, orbited and recovered a spacecraft; and sent the free-flying cargo carrier Dragon to the International Space Station (ISS) in 2012 - the first private company to do so.

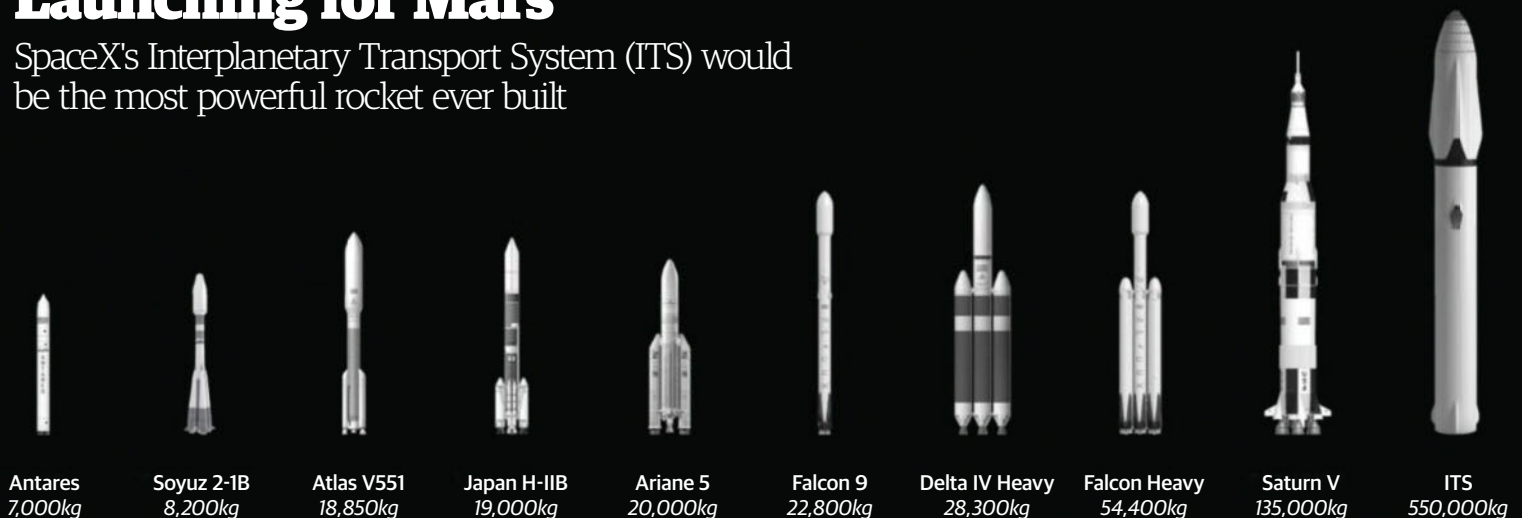
"The aim is to build a sustainable civilisation, as a way of future-proofing life ahead of the inevitable extinction event that will one day wipe all of us out"



SpaceX CEO, Elon Musk hopes to launch a reusable rocket and spacecraft to Mars as soon as 2022

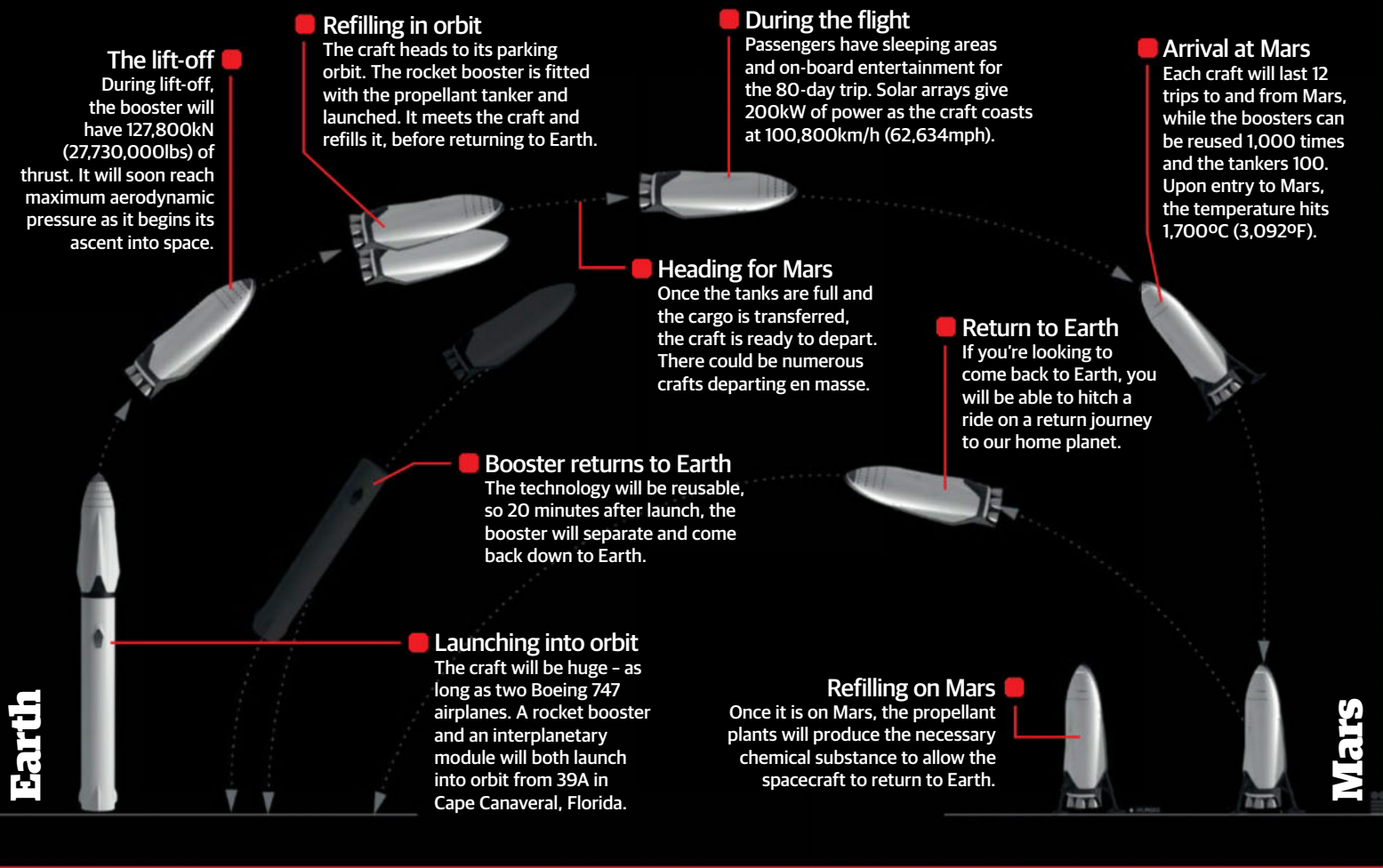
Launching for Mars

SpaceX's Interplanetary Transport System (ITS) would be the most powerful rocket ever built



How SpaceX will get you to Mars

SpaceX has already planned out how it intends to get people to the fourth planet from the Sun



The passengers disembark from the spaceship once it has reached Mars

“Musk admits it is likely to take between 40 and 100 years for a fully sustainable community to exist on Mars”

More recently, SpaceX has been working hard in developing reusable launch systems.

For its trips to Mars, the company will be using what it dubs the Interplanetary Transport System, or ITS for short. The idea is to reduce the cost per ton to make space travel relatively more affordable - perhaps one day getting it to as low as \$100,000 (around £80,000) - and there are four main components to this. The first is the need for the spaceships and vehicles to be fully reusable, as the longer they can be kept in service, the more cost-effective they become.

So while the launch window means the spaceship component can only be used once every two years or so, the boosters and tankers could be used many more times - “as frequently as you like,” says Musk - and this brings into play a significant cost saver,

which allows for the refilling of the spaceship in orbit. This can be performed multiple times, which reduces the size of the fuel tanks and allows for greater payload capabilities.

To get the spacecraft back to Earth so that it can be reused, a propellant production plant would be built on the Red Planet. “It would be pretty absurd to try and build a city on Mars if your spaceships just kept staying on Mars and not going back to Earth - that would give a massive graveyard of ships and you’d have to do something with them,” says Musk. Water ice in the soil and a carbon dioxide atmosphere would make the creation of propellant on Mars feasible but it’s important to make the right propellant. “We think methane is better across the board,” Musk suggests. With the systems in place, there would be test and exploratory missions before

paying humans would be allowed on board. This is expected to take some time and SpaceX already has the fact that two of its Falcon 9 rockets have exploded at the back of its mind ("the rocket booster [of the ITS] in many ways is a scaled up version of the Falcon 9," says Musk). Those incidents have prompted a call by US Republican politicians for NASA and the Air Force to lead an investigation over fears that lives could be put at risk in the future, while SpaceX wants to conduct its own probe.

Should everything go ahead as planned, though, what can we expect from the journey? Musk says passengers would spend their travel time in a pressurised section of the spaceship. There would be more than enough facilities on board the spaceships to keep people occupied, from restaurants to games and the inevitable stunning views. In time, Musk hopes the journey will be slashed to as little as 30 days but he still believes the longer travel times would pose few issues for travellers. "It's fairly manageable considering the trips people used to do in the old days, sailing voyages of six months or more," he says. The spaceships will also carry millions of tons of cargo and building materials for the creation of "iron foundries, pizza joints, you name it" on Mars. The aim is to send 1 million people, which would entail a total of 10,000 trips, unless SpaceX succeeds in doubling the capacity of the crew section to 200. Musk admits it is likely to take between 40 and 100 years for a fully sustainable community to exist on the Red Planet.

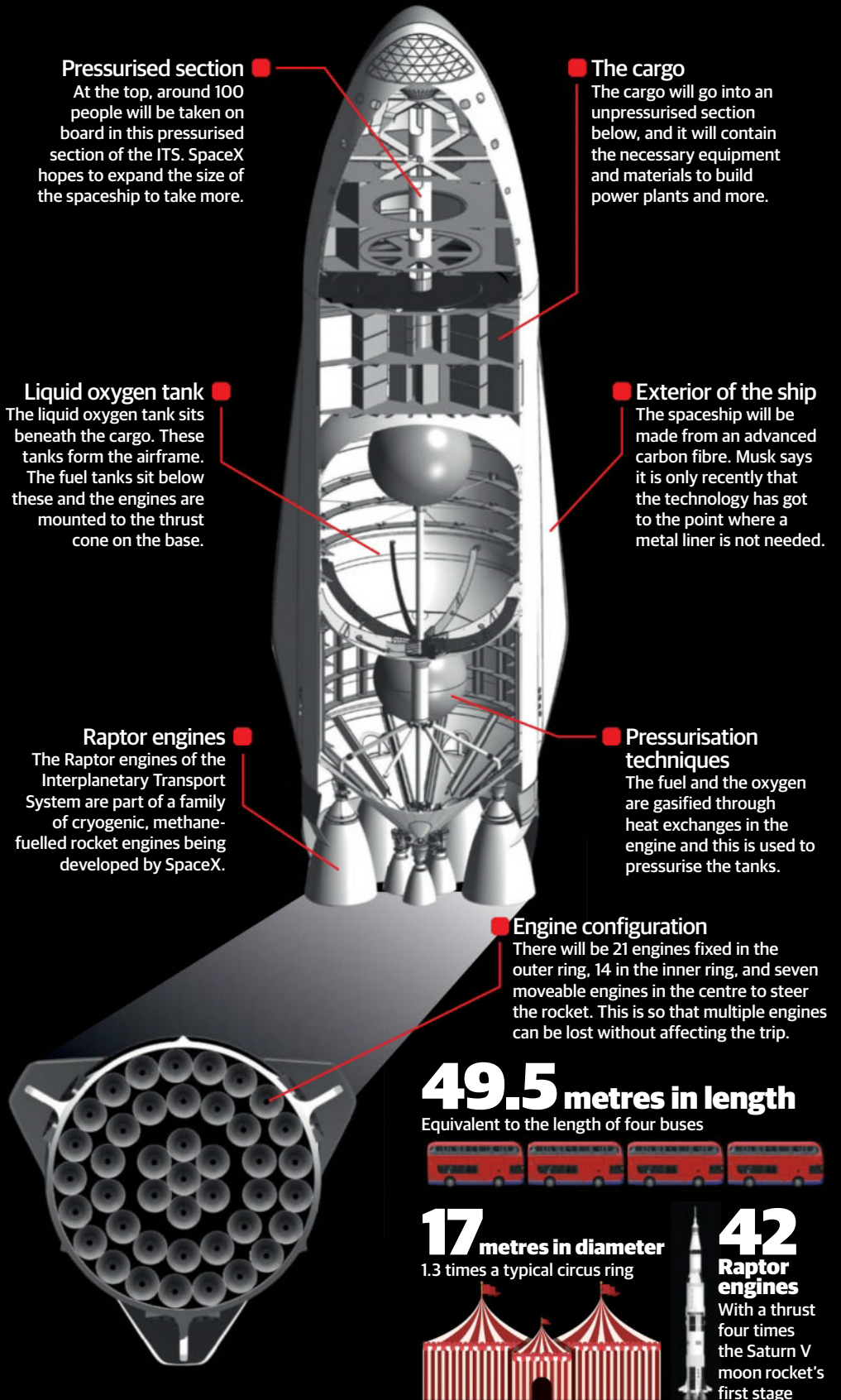
In the meantime, though, SpaceX is continuing to test its existing technology. Musk says that the accuracy of landing of its reusable ships is getting closer to the bull's-eye and he adds that a lot of work has been carried out in refining the heat shield technology to protect passengers as they arrive. The project will be funded by SpaceX's ongoing work with the launch of private satellites and the cargo missions it carries out to the ISS for NASA. The private sector is also interested in funding a Mars base, Musk adds. "Ultimately, this is going to be a huge public and private partnership and I think that is how the United States was established and many other countries around the world." He says that he is personally acquiring assets in order to generate the funds to make humans a multi-planetary species. "This is possible, the dream is real," he says. "The support will snowball over time."

And yet his ambition isn't stopping at Mars. The Interplanetary Transport System is actually a new name for SpaceX's Mars Colonial Transporter. In the future, he foresees propellant depots built on other planets and moons, allowing for hops from one celestial body to another in a bid to grant full access to the Solar System. In the meantime, he is content with targeting the fourth rock from the Sun, although, intriguingly, he is not the only one.

Indeed, a 21st century 'Space Race' is opening up. Boeing's CEO Dennis Muilenburg is confident his company will beat SpaceX to Mars while retailer Amazon's Jeff Bezos founded Blue Origin with much the same aim. NASA says it, "applauds all those who want to take the next giant leap and advance the journey to Mars", but adds that it [SpaceX] has made "extraordinary progress" of its own with regards to sustainable Mars exploration. Of course,

Interplanetary Transport System

The revolutionary rocket that will take humans to Mars



it's still early days and there are many questions to be answered. Aside from whether SpaceX really can scale up its Falcon 9 rockets (it hasn't done so yet), will passengers be screened for suitability and skills? Who will end up ruling Mars? How will the planet be powered (Musk suggests solar panels or geothermal)? What are the health implications? How will everyone rub along with one another? Will resources last and what happens the moment people get off?

Crucially, too, SpaceX has never actually sent a single person into space, let alone hundreds of thousands of people. It's clear a lot of work still needs to be done, but the idea is out there and there are many people powering towards the end goal. "If things go super well," Musk says, then we could have a Mars flight crew within the next ten years. "Anything that can be done to increase the desire for people to go to Mars, is a good thing," he says. "You want to create the dream of Mars in people's minds. It's a new frontier."

"What I really want to try and achieve here is to make Mars seem possible – like something we can achieve in our lifetimes"

Quickfire with Elon Musk

The CEO of SpaceX answers your questions on his newest space venture



Who should the first men, women and children to go to Mars be?

I think the first journeys to Mars are going to be very dangerous. The risk of fatality will be high, there's no way around it. So I would not suggest sending children. It would be basically, "are you prepared to die? That's okay, then you're a candidate for going." The thing that really matters is making a self-sustaining civilisation on Mars.

How will you keep people safe from radiation and how will they live on the planet?

My view on the radiation thing is that there will be some risk but it's not deadly. There will be some slight increase of cancer but I think it's relatively minor. You need to have some shielding, particularly if there's a solar flare or storm. Once you're on Mars, you have cut the radiation in half just because you have the planetary shield and there's at least some atmosphere. Over time, you could construct an artificial magnetic field to deflect high-energy particles.

Is it going to be a one-way trip?

I think it's important to give people an option of returning. The number of people who will be willing to move to Mars will be much greater if they know they have the option of returning, even

if they never actually return. Most people who went to the original English colonies in America didn't return to Europe even once, but some did. Just knowing that if you don't like it there you can come back, I think makes a big difference in people's willingness to go there in the first place. And in any case, we need the spaceship back so it's coming back. You can jump on board or not. You get a free return trip if you want.

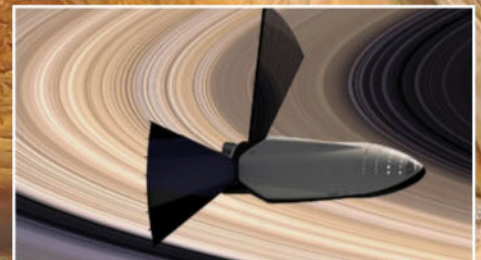
Will there be any physical requirements to go to Mars?

We're trying to make it so that anyone can go. There may be a few days of training, though.

How many resources are you putting into developing this right now?

Right now, the resources being put into the ITS are pretty low. Certainly well under five per cent of the company and maybe we're spending a few tens of millions of dollars on it right now. As we finish development of the final version of Falcon 9, which should be some time next year, and get the reusability of the boost stage and Dragon 2 sorted out, we'll gradually apply more and more resources to the interplanetary system. We will have most of the engineering team working on it within a year-and-a-half to two years.

The plan is to eventually journey to other planets and moons in the Solar System



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Ganymede, the largest Galilean moon, is thought to have a liquid water ocean beneath its crust

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Sophie Cottis-Allan



National Space Academy Education Officer
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Editor

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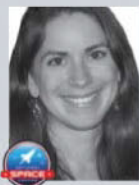
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Space Communications Manager

Tamela has a degree in astrophysics and writes for the National Space Centre Blog. She has eight years' experience in science communication.

SPACE EXPLORATION

Which of Jupiter's moons is the easiest to land on?

James Boss

Jupiter's four largest moons - the so-called Galilean moons - each have a solid surface that a spacecraft could potentially land on. But some are trickier than others due to their active geology and the intense radiation coming from Jupiter. Io, for example, is the closest of the Galilean moons and so receives the most intense radiation. Any spacecraft landing on Io would need to be extremely well shielded in order to survive, similar to the titanium shielding on the Juno spacecraft currently at Jupiter. Io's surface is also extremely dynamic because of its many active volcanoes, which means that selecting a stable landing site could be difficult.

Jupiter's largest moon, Ganymede, is further away from Jupiter so the radiation wouldn't be as intense and it also appears to have a relatively stable icy crust, making a landing easier to plan. But most importantly, Ganymede is scientifically very interesting because underneath its icy crust is thought to be a salty, liquid water ocean, perhaps capable of harbouring microbial life. Russia is currently investigating landing a spacecraft on Ganymede in the 2030s, as part of the European Space Agency's Jupiter Icy Moons Explorer (JUICE) mission, so we may soon know exactly how hard it is to land on a moon of Jupiter. **TM**

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We still need to find out more about plant growth in microgravity

SPACE EXPLORATION

Is it possible for a spacecraft to be self-sustaining?

Simon Dixon

Realistically, a self-sustaining craft would need to rely on plant life being able to flourish in space, taking in harmful carbon dioxide and converting it into oxygen, providing food and possible fuel. However, experimental contained biodomes on Earth have

failed to flourish without external intervention, and we still need to understand more about plant growth in microgravity before we can hope to produce enough food to sustain a crew.

Aspects of sustainability are already being used on the International Space Station (ISS). Around 93 per cent of the

water on board is recycled and large solar arrays generate electricity from the Sun's rays. Recently, the astronauts even ate the first space-grown salad.

By using the ISS as a test bed, we can improve our understanding and technology to eventually produce self-sustaining spacecraft. **SCA**

DEEP SPACE

Is space created as the universe expands?

Nick Barnes

As the universe expands we know the distances between objects is getting larger. The exact machinations of this process, however, are still unknown. An analogy often used is that it is similar to the surface of a balloon; the rubber of the balloon isn't really expanding from a central point but it is all expanding equally. As this happens, in the balloon analogy there isn't any extra rubber being created but rather it is just getting thinner.

This could be how it works in space but we are not sure. Nothing suggests that new 'space' or material is being created as space expands but we know that 'space' *is* expanding. We also know that everywhere is expanding at the same rate, as such there is no discernible centre of the known universe, and the exact mechanics of this expansion are still the subject of a lot of research. **JB**

The universe is expanding at the same rate in all directions

DEEP SPACE



How are binary planets made?

Terry Andrews

A binary planet refers to two planets of roughly equal mass orbiting each other, but so far these systems are just hypothetical. It's not too far-fetched an idea though. Binary stars and binary asteroids are common pairings in the universe, so it's possible that we may also find binary planets orbiting distant stars. How binary planets might form is still up for debate - one possibility is that two planets of similar mass gradually veer towards each other until they are locked into orbit by their gravity. But this probably wouldn't be a long-term coupling. From computer simulations, such planets are likely to either collide or slingshot away from each other. With over 100 billion stars in the Milky Way though, there is a good chance that at least some of these stars have binary planets orbiting them. **JB**

DEEP SPACE

How are brown dwarfs made?

Keith Jenkins

The stellar nursery

The life of a brown dwarf starts out on the right foot. Just like main sequence stars such as our Sun, these objects originate from the collapse of a huge cloud of gas and dust.

The young star

When a cloud of gas and dust caves in, gravity begins to pile up the material tightly to make a very young star - known as a protostar - at its centre.

The cool brown dwarf

Since they are not very visible to the human eye, telescopes need to observe brown dwarfs in infrared wavelengths to pick up their heat, which is considered to be very low compared to their blazingly hot and bright stellar cousins.

Brown dwarf types

Like stars, brown dwarfs sit in the classes L, T and Y. L dwarfs can be 1,727°C (3,141°F) while Y dwarfs are very cool. Some M-class stars can also be brown dwarfs.

Failure to fuse

In a main sequence star, gravity pushes so strongly inward that hydrogen fusion is kick-started in the core. The brown dwarf never reaches this stage and, before the temperatures get hot enough for hydrogen fusion to start, the brown dwarf reaches a stable state.

Colours and flavours

Belonging to different classes means that brown dwarfs contain different gases and colours. T dwarfs are a dark magenta and contain methane, water and ammonia, while Y dwarfs are browner and are likely to contain a good amount of water.

DEEP SPACE



NASA's James Webb Space Telescope is specially designed to observe infrared light and will help image exoplanets

Will we ever be able to see detail on an exoplanet?

Scott Parker

Yes, eventually. We're in a golden age of exoplanet discovery, with more than 3,000 confirmed planets around stars. For nearly all of these detections, we only have estimates of the planet's mass, its distance from its star, and possibly its diameter, but in the past few years, some nearby exoplanets have been photographed directly with large optical telescopes like the Very Large Telescope in Chile. This tells us whether the planet is hot and hellish like Venus or habitable like Earth. Maybe we will even detect gases produced by alien life - perhaps oxygen or methane.

Recently, an Earth-like planet was found around our closest star, Proxima Centauri; this will be a prime target for follow-up imaging with telescopes like the James Webb Space Telescope. **TM**

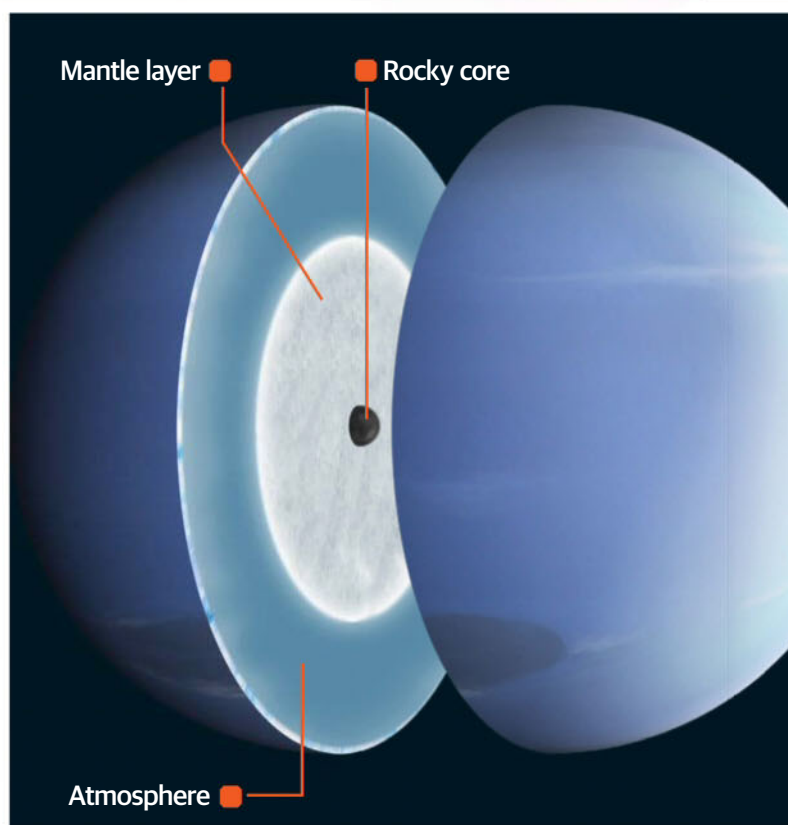
SOLAR SYSTEM

What's at the centre of the ice giants?

David Pringle

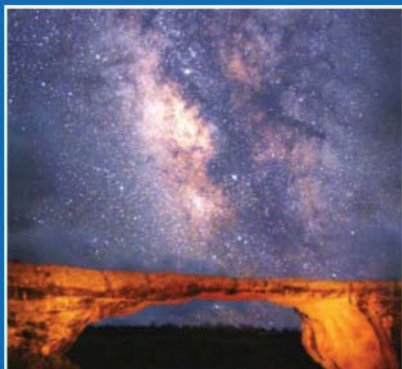
Current theories suggest that ice giant planets probably have a rocky core; a mixture of silicate rocks and metals like iron and nickel are thought to make up their core. This would help explain the densities we have calculated for these planets. The ice giants, Uranus and Neptune, are also thought to contain a lot of icy material, hence their name. The proportion of rock, ice and gas is currently up for debate, as various distributions fit with the observed properties of the planets.

At the moment, we don't have detailed enough science from the centres of these giant planets to verify their internal structure. However, there are discussions around potential missions to look into this. One such mission is Juno, which is currently investigating Jupiter, and gaining information about its internal structure is one of the craft's science goals. **JB**



Where can I go for the best dark sky sites?

Jon Harrison



Natural Bridges National Monument
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: Utah, US
Area: 30km²/12mi²



Brecon Beacons National Park
Bortle sky class: 3-5
Sky Quality Meter reading: 21.00 or above
Location: Brecon, Wales
Area: 1,347km²/520mi²



Galloway Forest Park
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: Dumfries & Galloway, Scotland
Area: 150km²/58mi²



Northumberland National Park and Kielder Water Forest Park
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: Northumberland, England
Area: 1,500km²/ 580mi²



NamibRand Nature Reserve
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: Namibia, Africa
Area: 1,722km²/665mi²

Cherry Springs State Park
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: Pennsylvania, US
Area: 0.5km²/0.2mi²

Death Valley National Park
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: California and Nevada, US
Area: 13,759km²/5,313mi²

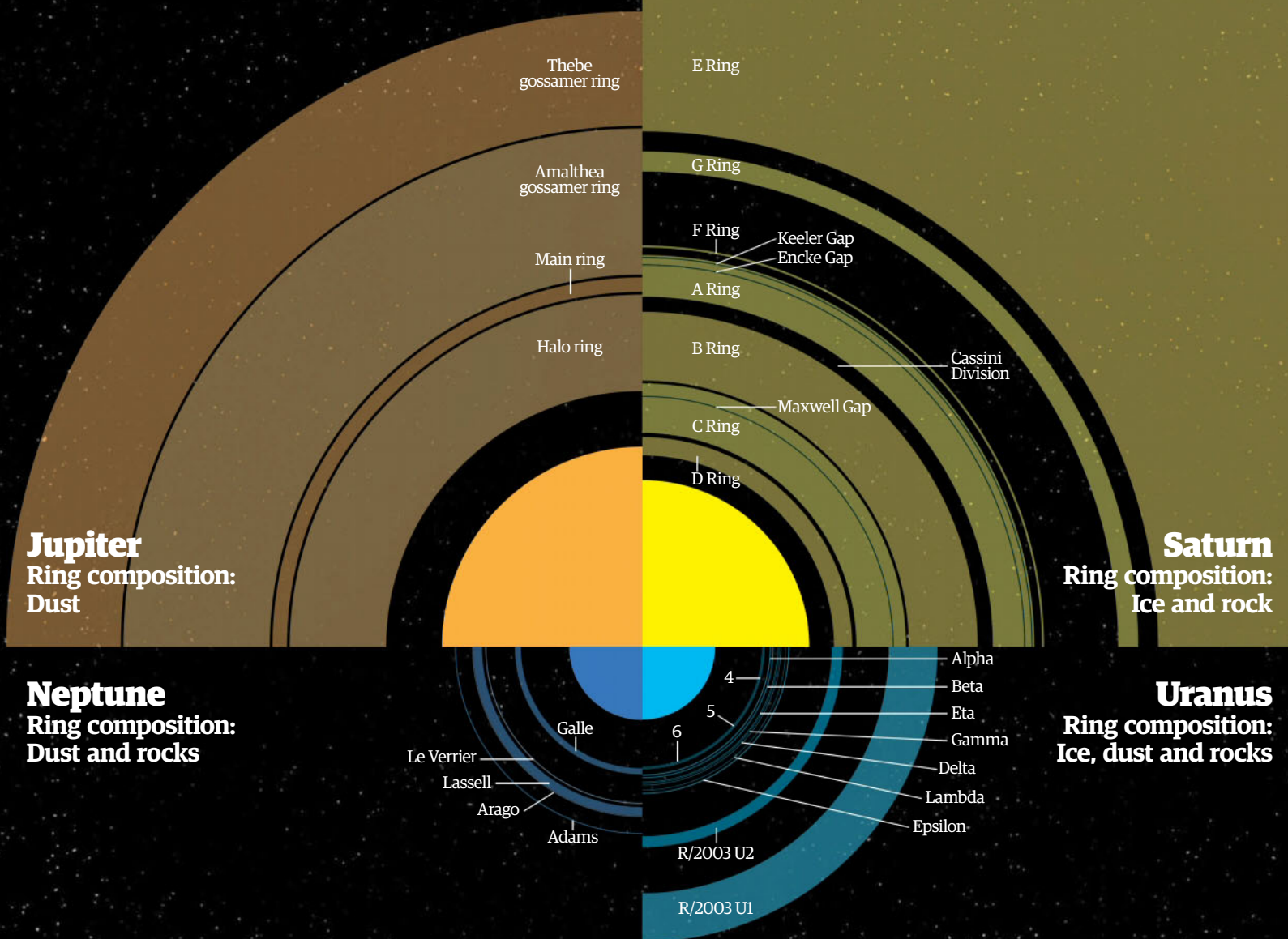


Aoraki Mackenzie International Dark Sky Reserve
Bortle sky class: 1-3
Sky Quality Meter reading: 21.75 or above
Location: South Island, New Zealand
Area: 4,300km²/1,660mi²

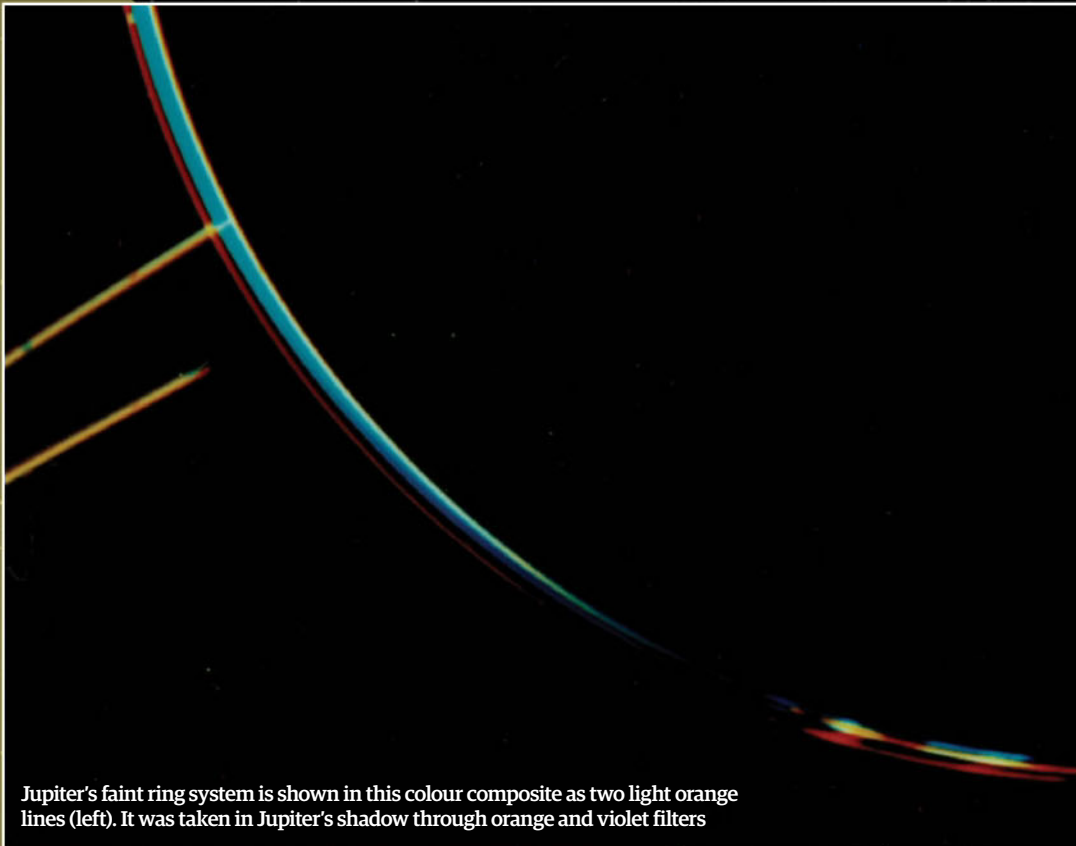
Which planets have rings?

Saturn is famously encircled by a bright and complex ring system, but it is not alone in possessing one

Rachel Hallas



Questions to...  @spaceanswers  /AllAboutSpaceMagazine  questions@spaceanswers.com

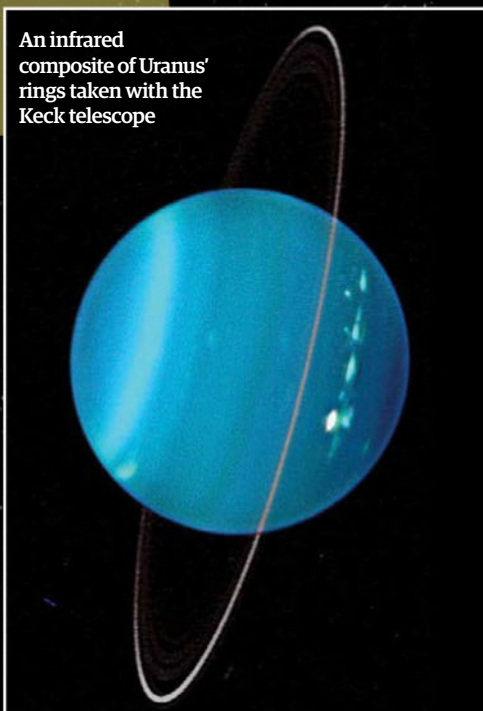


Jupiter's faint ring system is shown in this colour composite as two light orange lines (left). It was taken in Jupiter's shadow through orange and violet filters

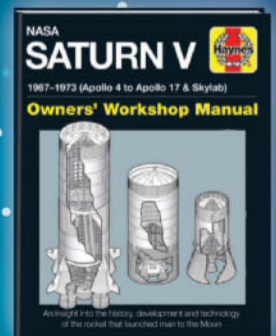
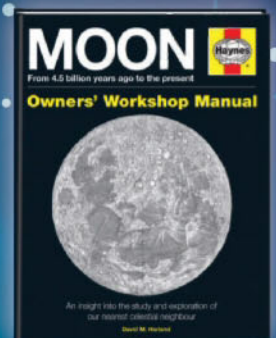
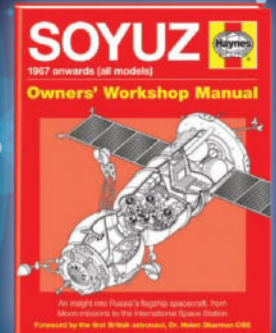
Ask "What's your favourite planet?" and the answer is likely to be "Saturn". Saturn's rings have become the graphic shorthand for planets, from logos to bed covers to stickers. But Saturn is not alone in possessing a planetary ring system, with four planets and two dwarf planets in the Solar System alone also boasting rings. Planetary rings are made up of lumps of dust and ice orbiting their parent body like billions of tiny moons. It is theorised that they are made of debris left behind from the formation of the planet, or from the collision and destruction of moons, or from a moon that got too close to the planet and was pulled apart by tidal forces. Saturn's rings are the most famous in the Solar System and were a source of great puzzlement when Galileo Galilei first trained a telescope on the planet in 1610; at first he thought Saturn was a triple planet. It was not until 1655 that Christiaan Huygens realised that what he was seeing was in fact a disc! The rings consist of seven major divisions, generally of the same thickness but of greatly varying density. Saturn's many moons also affect the rings, with Prometheus' gravity shepherding the edge of one into a sharp boundary, and Enceladus adding ice crystals to the E Ring. Despite being closer to us, Jupiter's ring system was only discovered when Voyager 1 flew past the gas giant in 1979. It has four sections believed to be made up of dust, but it is very diffuse compared to Saturn's ring system. Next up is Uranus, whose rings are much more distinct than Jupiter's, yet they were also only discovered in the 1970s due to the planet's great distance from Earth. Uranus famously rotates on its side, so its rings appear to be north-south as they orbit around the tilted equator. Neptune also has a ring system, which is largely made up of dust rather than ice. The density of Neptune's ring system approaches that of Saturn's thinner rings, but the rings remain

faint and dark due to organic material within them. In 2013, dips in brightness of stars observed around the dwarf planet Chariklo, orbiting between Saturn and Uranus, led to the conclusion that it has a ring system. Chiron, another dwarf planet in the same region, is also thought to have rings. Both Chiron and Chariklo are centaurs, small icy bodies crossing the orbits of giant planets. It's thought that their rings may have formed from surface material that was pulled by tidal forces when they got too close to these giant planets. **RH**

An infrared composite of Uranus' rings taken with the Keck telescope



A WORLD OF INFORMATION



WAITING TO BE DISCOVERED



Haynes
shows you how





STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

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What's in the sky?



**12
NOV**



The Taurids reach their peak of around ten meteors per hour

**12
NOV**



Conjunction between the Moon and Uranus in Pisces

**18
NOV**



The Leonids reach their peak of around 20 meteors per hour

**21
NOV**



Dwarf planet Ceres reaches opposition in Cetus

**25
NOV**



Conjunction between the Moon and Jupiter in Virgo

**27
NOV**



The Moon appears small as it reaches its furthest point from Earth



Jargon buster

Conjunction

This is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Greatest elongation

This is when the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as bright evening stars during greatest eastern elongations and as morning stars during western elongations.

Declination (Dec)

Declination tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it is from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

This is when a celestial body is in line with the Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter in the sky.

**14
NOV**



The Moon appears large as it makes its closest approach to Earth

**22
NOV**



Asteroid 18 Melpomene reaches opposition in Cetus

Naked eye

Binoculars

Small telescope

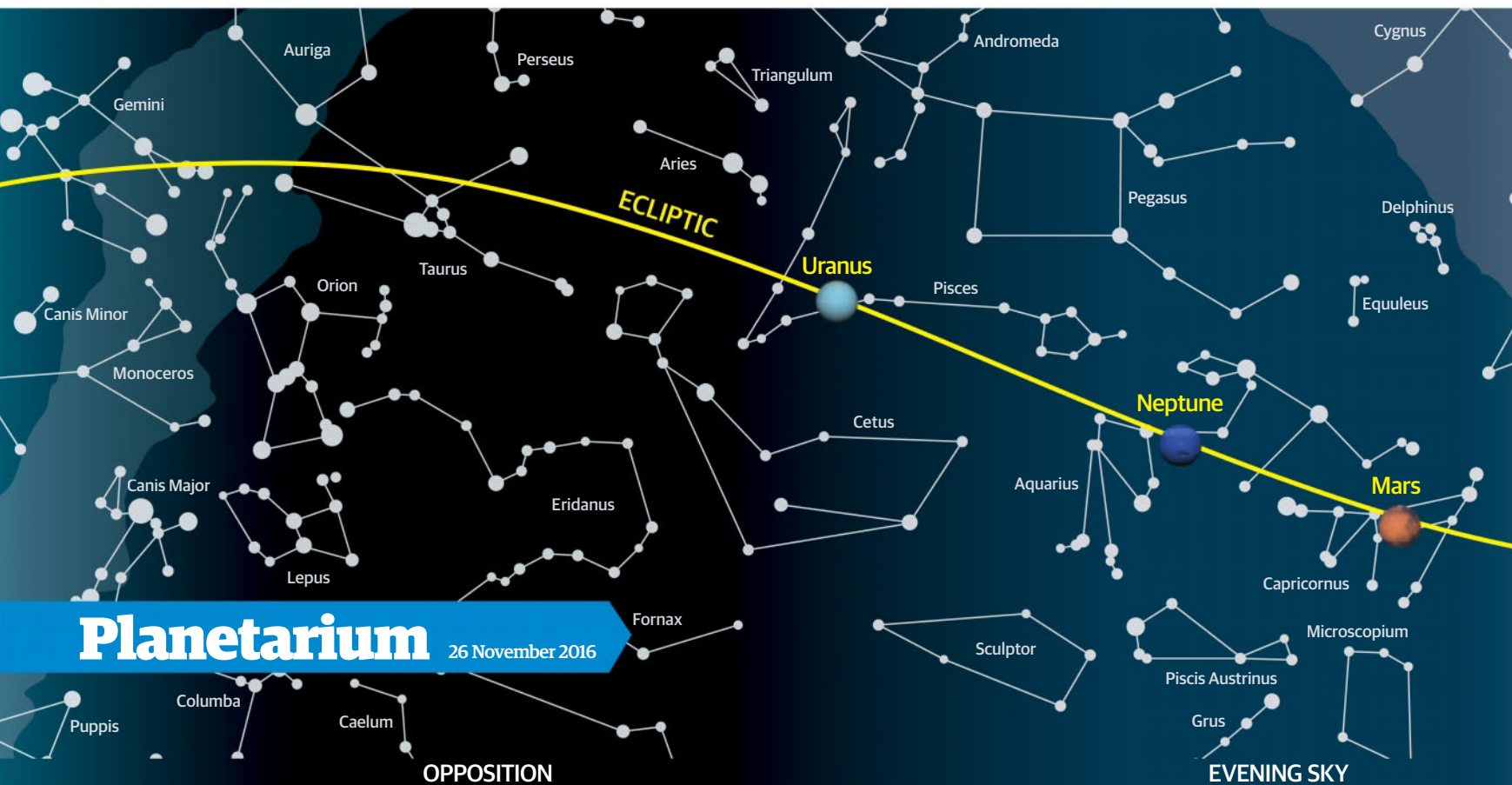
Medium telescope

Large telescope

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

ALIENS
Science Asks: Is There Anyone Out There?



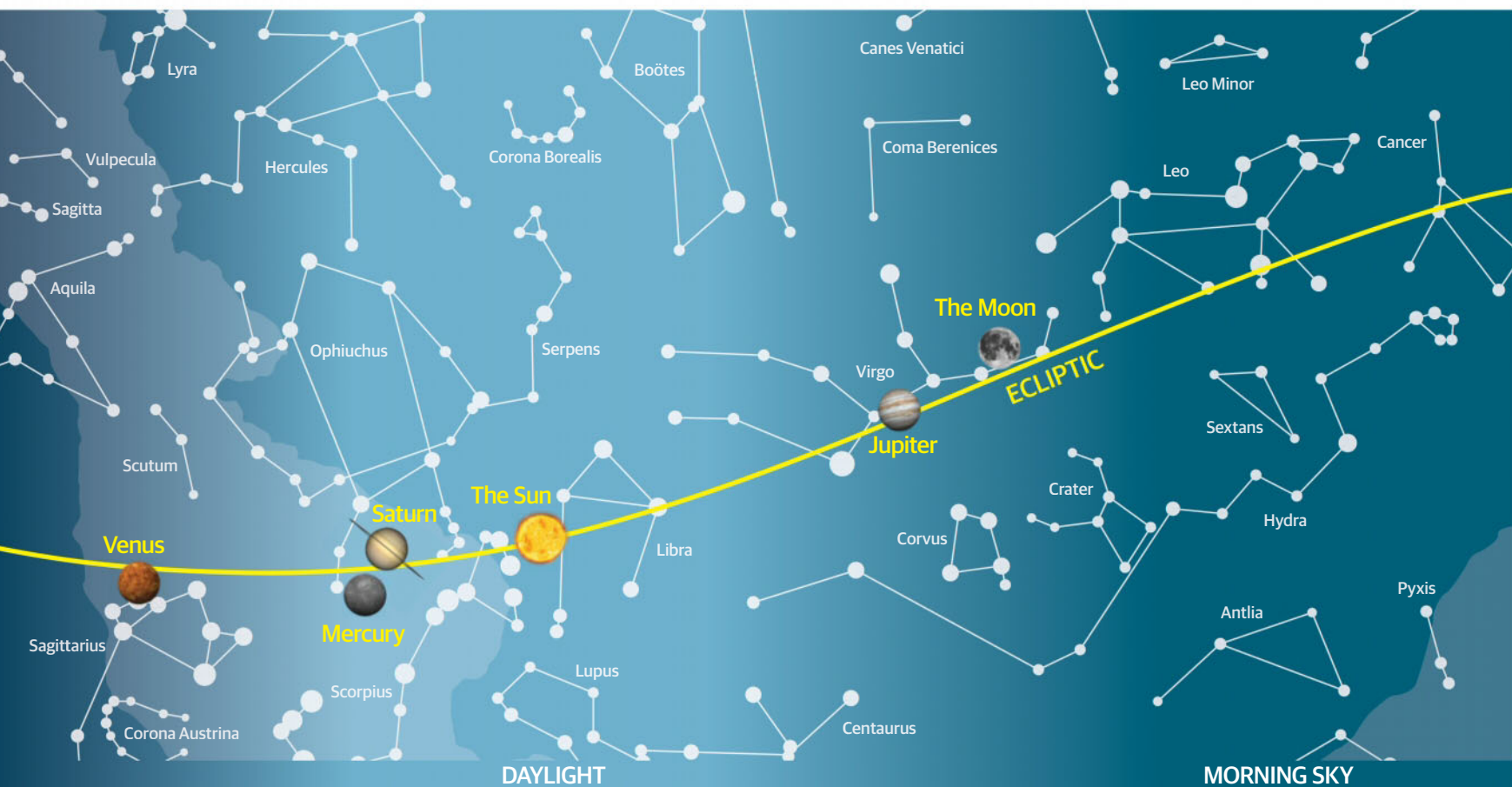
Moon phases

				10 NOV 80.8% ☾ 01:18 ☀ 14:37	11 NOV 89.4% ☾ 02:34 ☀ 15:05	12 NOV 95.8% ☾ 03:54 ☀ 15:34	13 NOV 99.3% ☾ 05:15 ☀ 16:07
14 NOV FM 99.6% ☾ 06:37 ☀ 16:44	15 NOV 99.5% ☾ 07:58 ☀ 17:28	16 NOV 96.5% ☾ 09:12 ☀ 18:20	17 NOV 90.5% ☾ 10:17 ☀ 19:19	18 NOV 82.3% ☾ 11:12 ☀ 20:24	19 NOV 72.5% ☾ 11:56 ☀ 21:32	20 NOV 62.0% ☾ 12:33 ☀ 22:41	
21 NOV LQ 51.2% ☾ 13:03 ☀ 23:48	22 NOV 40.8% ☾ 13:29 ☀ ---	23 NOV 31.1% ☾ 00:54 ☀ 13:53	24 NOV 22.3% ☾ 01:59 ☀ 14:15	25 NOV 14.7% ☾ 03:03 ☀ 14:38	26 NOV 8.6% ☾ 04:05 ☀ 15:02	27 NOV 4.0% ☾ 05:08 ☀ 15:27	
28 NOV 1.2% ☾ 06:09 ☀ 15:56	29 NOV NM 0.2% ☾ 07:09 ☀ 16:29	30 NOV 1.1% ☾ 08:07 ☀ 17:08	1 DEC 4.0% ☾ 09:00 ☀ 17:53	2 DEC 8.7% ☾ 09:49 ☀ 18:44	3 DEC 15.2% ☾ 10:32 ☀ 19:42	4 DEC 23.3% ☾ 11:10 ☀ 20:45	
5 DEC 32.7% ☾ 11:43 ☀ 21:51	6 DEC 43.2% ☾ 12:12 ☀ 23:01	7 DEC FQ 54.3% ☾ 12:40 ☀ ---	8 DEC 65.6% ☾ 00:14 ☀ 13:06				

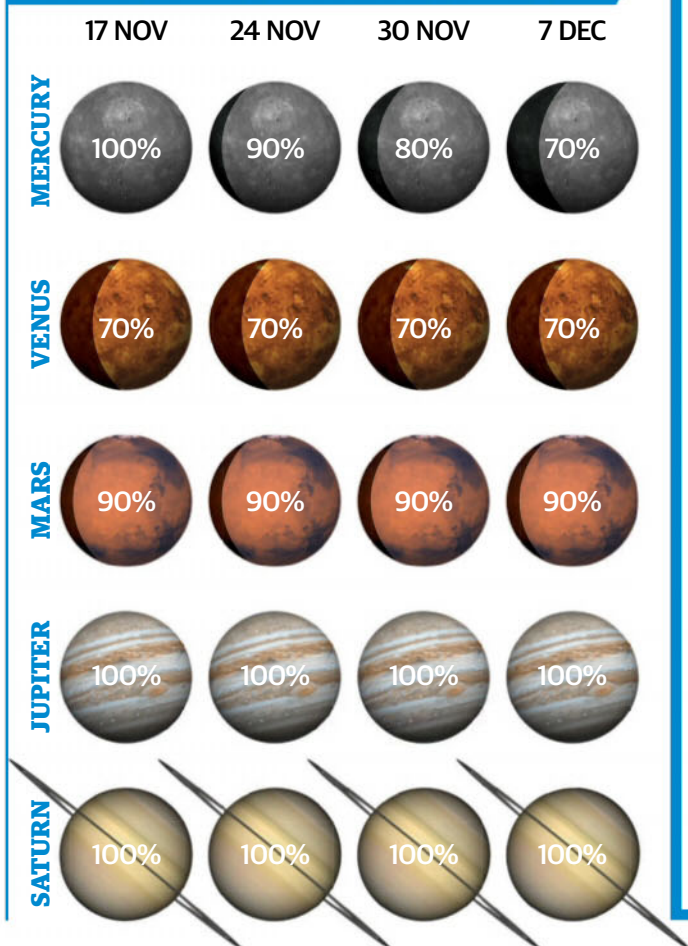
% Illumination
☾ Moonrise time
☾ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	10 Nov	15h 32m 40s	-20° 07' 09"	Libra	-1.5	07:58	16:27
	17 Nov	16h 17m 19s	-22° 59' 29"	Scorpius	-1.6	08:34	16:25
	24 Nov	17h 02m 35s	-24° 55' 37"	Ophiuchus	-1.7	09:05	16:29
	30 Nov	17h 41m 03s	-25° 44' 37"	Ophiuchus	-1.9	09:26	16:37
	7 Dec	18h 23m 02s	-25° 38' 00"	Sagittarius	-2.2	09:39	16:53
VENUS	10 Nov	17h 47m 19s	-25° 27' 30"	Sagittarius	-4.5	10:49	18:05
	17 Nov	18h 24m 20s	-25° 34' 04"	Sagittarius	-4.5	10:59	18:13
	24 Nov	19h 01m 01s	-25° 04' 51"	Sagittarius	-4.6	11:04	18:26
	30 Nov	19h 31m 53s	-24° 12' 14"	Sagittarius	-4.6	11:05	18:39
	7 Dec	20h 06m 54s	-22° 40' 51"	Sagittarius	-4.7	11:02	18:57
MARS	10 Nov	20h 11m 43s	-21° 49' 32"	Capricornus	-0.0	12:47	20:54
	17 Nov	20h 33m 07s	-20° 30' 50"	Capricornus	0.0	12:32	20:57
	24 Nov	20h 54m 19s	-19° 02' 27"	Capricornus	0.1	12:17	20:59
	30 Nov	21h 12m 18s	-17° 39' 36"	Capricornus	0.2	12:03	21:02
	7 Dec	21h 33m 02s	-15° 55' 29"	Capricornus	0.2	11:46	21:06
JUPITER	10 Nov	12h 48m 43s	-03° 59' 26"	Virgo	-1.7	03:45	15:12
	17 Nov	12h 53m 41s	-04° 29' 52"	Virgo	-1.7	03:25	14:47
	24 Nov	12h 58m 27s	-04° 58' 42"	Virgo	-1.8	03:05	14:23
	30 Nov	13h 02m 21s	-05° 21' 59"	Virgo	-1.8	02:47	14:00
	7 Dec	13h 06m 39s	-05° 47' 18"	Virgo	-1.8	02:26	13:35
SATURN	10 Nov	16h 56m 01s	-21° 16' 28"	Ophiuchus	1.3	09:28	17:43
	17 Nov	16h 59m 20s	-21° 22' 12"	Ophiuchus	1.3	09:05	17:18
	24 Nov	17h 02m 45s	-21° 27' 43"	Ophiuchus	1.3	08:41	16:53
	30 Nov	17h 05m 44s	-21° 32' 14"	Ophiuchus	1.3	08:21	16:32
	7 Dec	17h 09m 15s	-21° 37' 11"	Ophiuchus	1.3	07:58	16:07



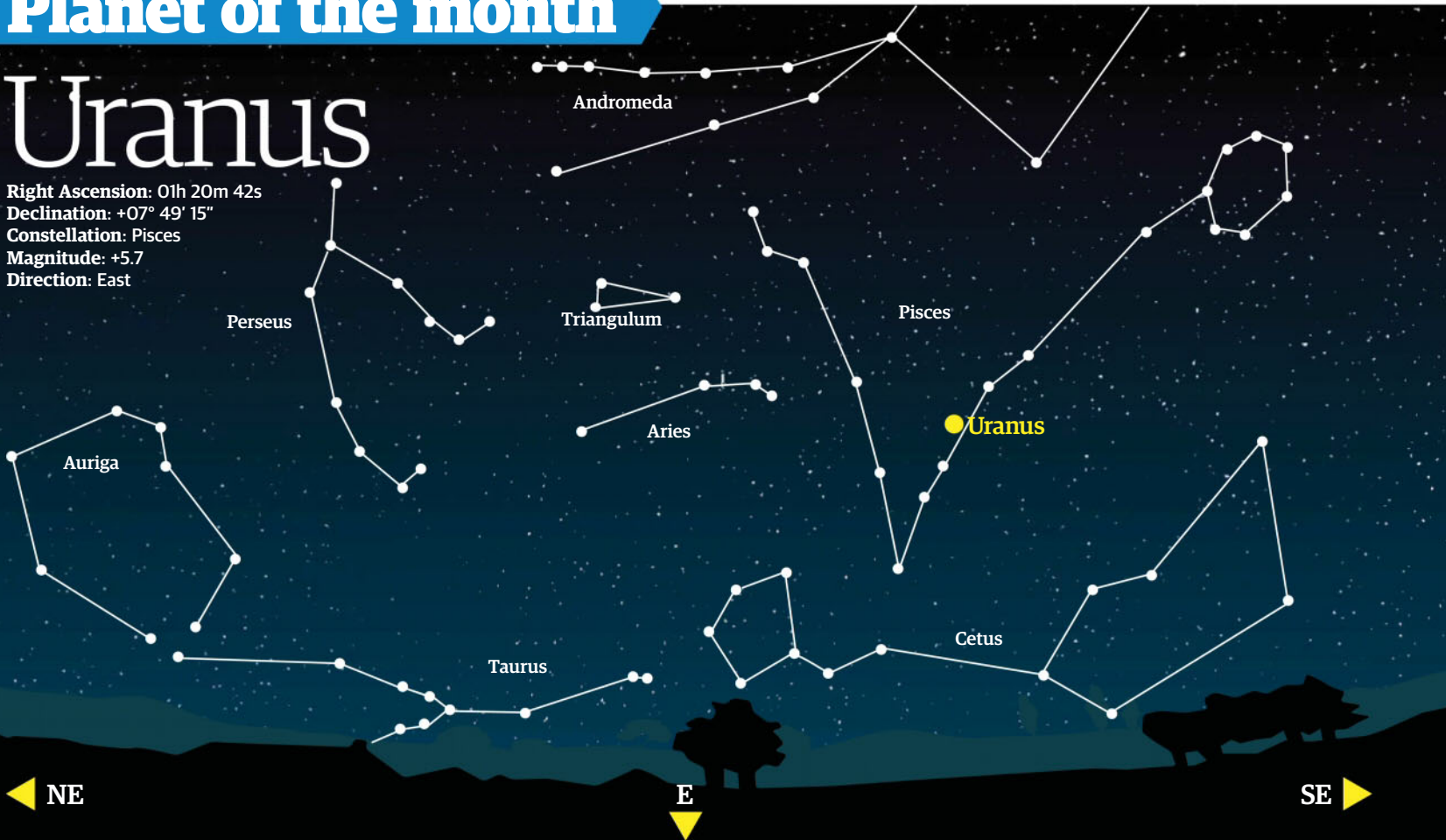
This month's planets

Planet-watchers are spoiled for choice this month, with bright planets on view both after sunset and before sunrise...

Planet of the month

Uranus

Right Ascension: 01h 20m 42s
Declination: +07° 49' 15"
Constellation: Pisces
Magnitude: +5.7
Direction: East



19:00 GMT on 12 November

Discovered on 13 March 1781 by William Herschel, Uranus is now often referred to as an 'ice giant' world by planetary scientists, to help distinguish it - and its neighbour, Neptune - from the gas giants. Compared to its much larger and more garish attention-seeking neighbours, Jupiter and Saturn, Uranus is rather shy and bland. It is 'just' four-times wider than Earth and could 'only' hold 63 Earths. Its system of 27 moons is far smaller than both Jupiter's and Saturn's, and its system of rings is darker and less impressive-looking. But Uranus shouldn't have an inferiority complex because it is an incredible world in its own right.

The most striking thing about Uranus is the way it orbits the Sun; instead of spinning around it on its polar axis, like a top, or a spinning coin, Uranus rolls around the Sun on its equator, with its poles facing towards and away from the Sun. Scientists think a huge impact in the planet's past knocked it off its axis, leaving it to trundle around the Sun like a barrel. And it trundles very slowly: one Uranus year is 84 Earth years. But Uranus spins on its axis so quickly - one Uranus day is just 17 hours long - that there are 43,000 days in a Uranian year. That's a long wait for your birthday or Christmas presents!

To date, only one probe has visited Uranus. Voyager 2 whooshed past it in 1986, just four days before the Challenger space shuttle disaster. It returned the only close-up images we have of Uranus and its moons so far. Thankfully, modern telescopes like Keck and Hubble can resolve the largest features in its atmosphere, such as bands of cloud and its bright storms, which race around the planet, propelled by howling winds with speeds of up to 900 kilometres (560 miles) per hour.

With a magnitude of 5.7, Uranus is technically a naked eye planet, and is visible all night through the coming month. However, if you want to spot

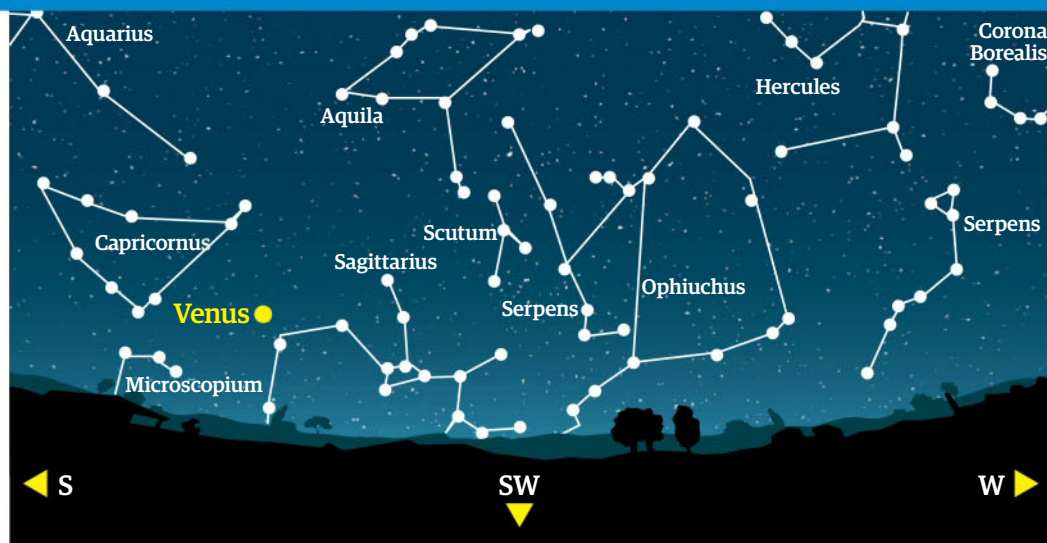
it without any optical assistance you'll need to know exactly where it is and be observing from a dark sky location. Uranus isn't bright enough to draw the eye like any of the other planets and any glow from streetlights will hide it. But with a good star chart you'll spot Uranus as a 'star' around a third of the way up the right side of the 'V' of Pisces, very close to Zeta Piscium.

Uranus' green colour is only apparent through binoculars or a telescope on a night with no Moon, so it's unlikely you'll see its subtle, aventurine-green hue on the night of 12 November, when the almost full Moon is blazing to the planet's lower left.



Venus

16:00 GMT on 3 December

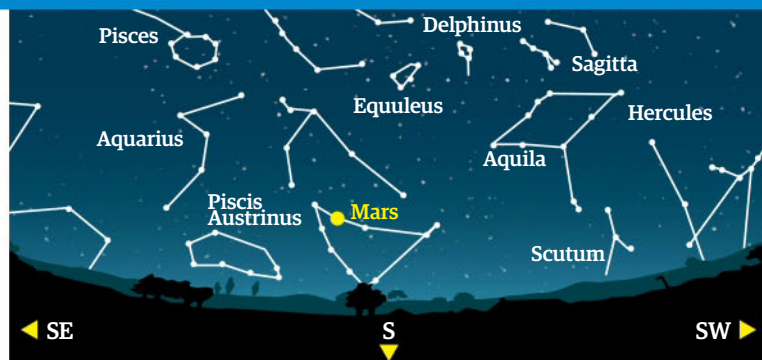


Right Ascension: 19h 47m 02s
Declination: -23° 36' 52"
Constellation: Sagittarius
Magnitude: -4.1
Direction: South

Venus is already an impressive evening star, blazing in the southwest after sunset, but its appearance this month is really just the warm-up act for its show-stopping performance over Christmas and the New Year. At magnitude -4.1, Venus is obvious to the naked eye as soon as the sky starts to darken. And as twilight shifts in hue from marmalade orange to rich purple, Venus brightens, shining like a silvery spark in the sky. By 2 December the young Moon will be close to Venus. The view should be especially beautiful in the early evening on 3 December, when the slim crescent Moon - the dark part of its disc glowing softly with lavender-blue 'Earthshine' - will be directly above Venus.

Mars

18:00 GMT on 3 December



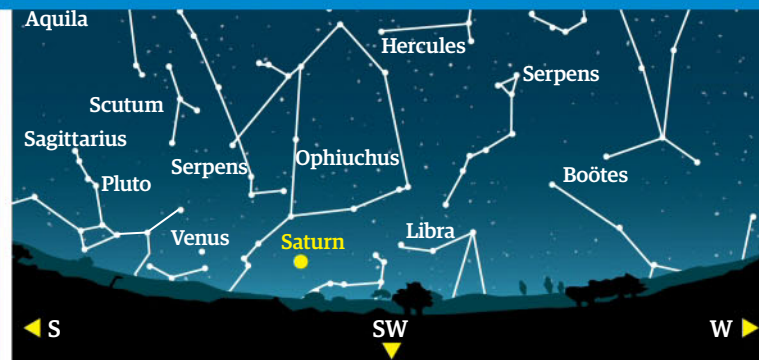
Right Ascension: 21h 21m 14s
Declination: -16° 55' 54"
Constellation: Capricornus
Magnitude: +0.2
Direction: South

Mars is now little more than an orange-hued star low in the southern

sky after dark. At magnitude +0.2, it is not striking but it is still visible to the naked eye. Binoculars will enhance its hue, and a small telescope will reveal its gibbous, orange disc, but little more. Look for Mars' close encounter with the Moon after sunset on 5 December.

Saturn

16:00 GMT on 10 November



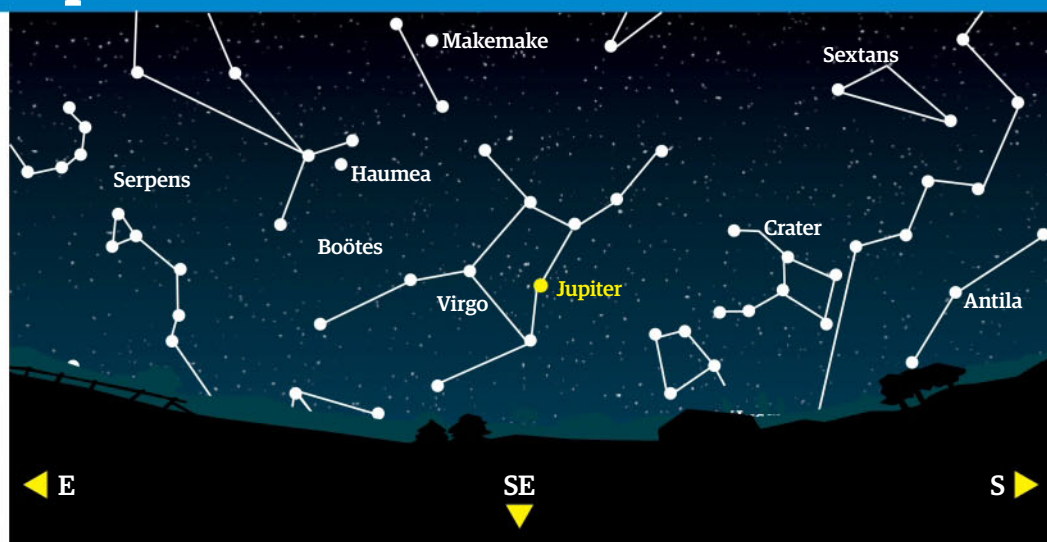
Right Ascension: 16h 56m 01s
Declination: -21° 16' 28"
Constellation: Ophiuchus
Magnitude: +1.3
Direction: Southwest

In early November Saturn is like a golden-hued star low in the southwest.

At magnitude +1.3, it is visible to the naked eye in dark skies but you may struggle to find it in the twilight. Binoculars will help you pick it out, enhancing its brightness and colour. By November's end Saturn will set just half an hour after the Sun.

Jupiter

5:00 GMT on 10 December



Right Ascension: 13h 08m 24s
Declination: -05° 57' 29"
Constellation: Virgo
Magnitude: -1.8
Direction: Southeast

Jupiter is a beautiful morning star this month. At the start of November the gas giant rises at around 4am, moving a little further away from the Sun each dawn until, by early December, it rises four hours before it. At magnitude -1.8, Jupiter is bright enough to be seen from light-polluted locations, but it will be a stunning sight if you can see it under a dark sky, putting to shame Virgo's brightest star, Spica, which the planet is slowly moving towards as the days pass. Before dawn on 24 November, a lovely crescent Moon will shine above and to the right of Jupiter, and the next morning it will be very close to Jupiter on its left, directly above Spica. Binoculars will show up to four of Jupiter's family of 67 moons.



Moon tour

Theophilus crater

Get to know one of the most striking but overlooked impacts on the lunar surface

Top tip!

When observing the Moon through a telescope, reduce its brightness with a cardboard mask or fit a Moon filter to your eyepiece to cut down any glare.

© NASA

As November slides into December, turbulent weather fronts often sweep across the country, scrubbing the atmosphere clean of haze to produce the first frosty nights of the year, with brittle air perfect for lunar observations. On these beautifully still nights the Moon seems brighter and is a dazzling sight through binoculars or a telescope. It's always tempting to look at your favourite lunar features, but this month why not track down something you'll almost certainly have seen before but not spent time looking at properly?

Sandwiched between northern Sinus Asperitatis and the dark stain of Mare Nectaris to the southeast, Theophilus is one of the most striking craters on the Moon. Named after the 23rd Pope of Alexandria, the crater is best seen four or five days after new Moon and just before last quarter, when it is close to the terminator. During full Moon, when the Sun is overhead, the crater's features are washed out and it looks more like

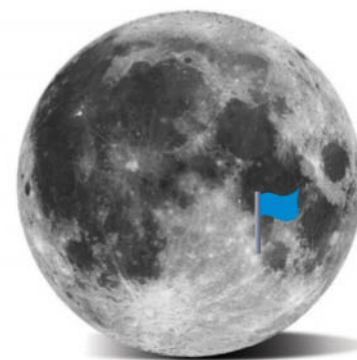
a white smoke ring than a pit, but it is still easy to see. Theophilus is a classic 'Tycho class' crater, closely resembling 'celebrity' craters like Copernicus, Eratosthenes and Tycho itself. At 100 kilometres (62 miles) wide and 3.2 kilometres (two miles) deep, it has a relatively flat, lava-flooded floor, pitted with many far smaller 'buckshot' craters.

A quartet of 1.4-kilometre (0.8-mile) high mountainous peaks rise up from Theophilus' floor and viewed with a high magnification, they give the impression of a single peak hacked into four pieces. The tallest two peaks, on the western side, cast dramatic triangular shadows when the Sun's light strikes them at low angles. Like many other craters its size, Theophilus has a sharp rim and gently sloping walls. These are broken up with terraces, ledges and shelves on the eastern side, while much of the floor on the crater's western side has been covered by landslides. Like the great crater Ptolemaeus, Theophilus is

also one half of a double crater. It was blasted out of the Moon by an impact that obliterated the northeastern corner of another crater, Cyrillus. Although no major ejecta rays are visible stretching away from Theophilus - not even at full Moon - considerable amounts of material were scattered across the Moon when it formed. Some of this material was collected by the crew of the Apollo 16 mission, which landed in the Descartes Highlands region in April 1972.

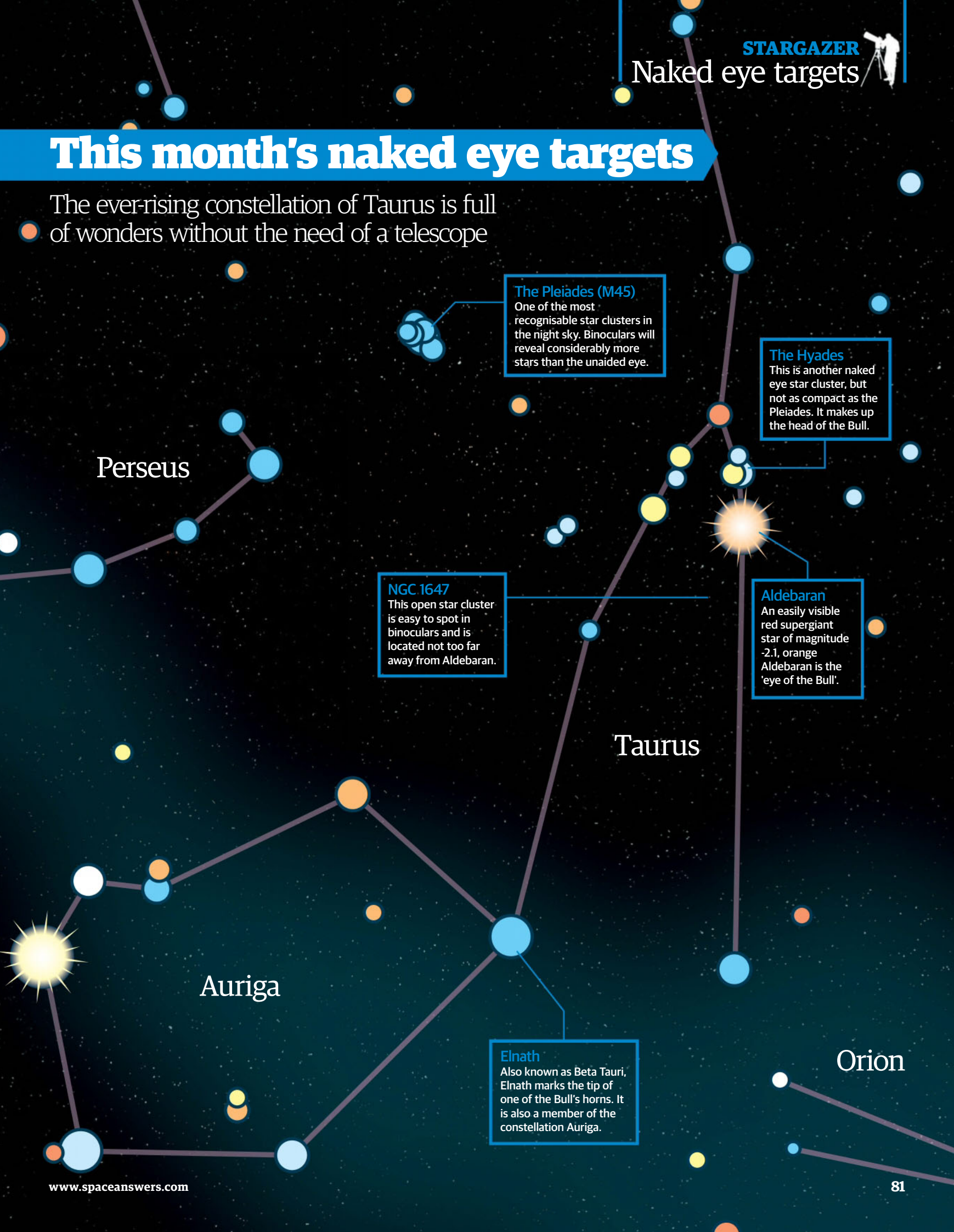
So, when's the best time to see it? In early November, with the Moon approaching full, Theophilus is fully illuminated and shows virtually no surface relief. But by 17-18 November the crater becomes prominent as the Moon wanes. During the next evening the terminator rolls over the crater and it is plunged into darkness. It reappears on 4 December as the first rays of sunlight strike its walls. The Moon will be a beautiful slender crescent, low in the southwest after sunset. On 5 December,

Theophilus should look its best for the month as sunlight bathes its pitted floor and central peaks. The Moon will be close to Mars in the sky, and the dark part of the Moon's face should glow with lovely grey-blue 'Earthshine', but don't let that distract you from enjoying Theophilus at its best! By 8 December, with the Moon approaching first quarter again, Theophilus will sink back into the lunar glare once more.



This month's naked eye targets

The ever-rising constellation of Taurus is full of wonders without the need of a telescope



The Pleiades (M45)

One of the most recognisable star clusters in the night sky. Binoculars will reveal considerably more stars than the unaided eye.

The Hyades

This is another naked eye star cluster, but not as compact as the Pleiades. It makes up the head of the Bull.

Perseus

NGC 1647

This open star cluster is easy to spot in binoculars and is located not too far away from Aldebaran.

Aldebaran

An easily visible red supergiant star of magnitude -2.1, orange Aldebaran is the 'eye of the Bull'.

Taurus

Auriga

Elnath

Also known as Beta Tauri, Elnath marks the tip of one of the Bull's horns. It is also a member of the constellation Auriga.

Orion



How to...

Capture a meteor shower using time-lapse

Photographing 'shooting stars' can be quite tricky, but here's a method that will help catch those quick flashes of light

You'll need:

- ✓ DSLR camera
- ✓ Wide-angle lens
- ✓ Sturdy tripod
- ✓ Intervalometer
- ✓ Spare memory card

There are meteor showers which occur regularly, some of which can give spectacular displays. The Leonids shower, which peaks this November, is certainly one of them. But photographing them can be a challenge! It seems to be the case that your camera is never pointing in the right direction, or the shutter is never open when a really nice shooting star crosses the sky.

However, if you use a wide-angle lens and a programmable shutter release for your DSLR camera - sometimes known as an 'intervalometer' - which controls your camera so you don't have to, you can increase your chances of getting at least one or two and probably more meteors streaking across the frame. There is no particular direction in which to point your camera, although near the zenith - that's straight up - is

often good for those nice long streaks. If you point the camera to the radiant, the point from where the meteors appear to emanate, which in this case is in the constellation of Leo, you will likely only get short meteor streaks, although this can still look effective.

Setting up your camera and programmable shutter release carefully is important for good results. It's advisable to try out a few test shots a couple of nights before the peak of the meteor shower - the peak takes place on the night of 17-18 November. This will ensure that everything is working as it should. You'll need to have exposures of 20 to 25 seconds and an ISO setting of 800 to 1600, depending on local conditions.

Good focus is key, so you'll need to turn off the 'auto-focus' on your camera and set it manually. Set the intervalometer for continuous shooting

and make sure your lens is 'wide open', that is, set at $f/2.8$ or however low it can go. Be aware of the dreaded dew; check your lens from time to time to make sure it hasn't fogged up. You can use a 'dew heater band' wrapped around the lens if the air is particularly damp. A hand towel wrapped around the camera body will help keep the water off it, too. Save the images as RAW files or RAW + medium JPEG. RAW files are uncompressed and will fill up a memory card quite rapidly, so have a spare card to hand.

The Moon will be in its waxing gibbous phase and may interfere with fainter events, so it may be best to wait until after midnight before you start shooting, just to make sure the Moon has fully set. Take lots of shots and hopefully you'll catch some Leonid meteor streaks on at least some of the frames. Good luck!

Tips & tricks

Take extended exposures

A DSLR camera will be able to take extended exposures up to 30 seconds in length. Just right for meteors!

Use a wide-angle lens

Either a zoom lens that can go down to at least 18mm, or a dedicated lens of 18mm focal length or less, is ideal.

Get a steady tripod

You'll need a tripod that's really sturdy and doesn't shake if there's a breeze.

Use an intervalometer

This is a programmable shutter release that attaches to your DSLR. It controls the duration and frequency of frames.

Take a spare memory card

When you are shooting in RAW you'll need a large memory card in your camera and a spare one!



Improving your meteor pictures

Here's how to get some great photographs of the Leonids

Make sure that you have a good focus. You can do this by zooming in on your view screen and slowly adjusting the focus on your lens. Don't be guided just by the infinity focus mark on the lens, as this may not be accurate. Local light pollution may make a difference to what ISO setting you use. You'll need

to experiment to see what gives the best result. Also, once you have positioned your camera and framed your shot, avoid the temptation to move it just because you see a bright meteor in a part of the sky where your camera isn't pointing. The next one could be right through your frame!

Send your photos to
photos@spaceanswers.com



1 Get your digital camera ready

Set up your DSLR camera to an exposure of 20-25 seconds and an ISO setting of 800-1600, depending on sky conditions. Use a red torch to help you.



2 Set up your tripod

After unfolding your tripod, make sure that everything is locked in position and sturdy. You don't want anything 'sagging' mid-shot.



3 Adjust the focus

Check the focus of your camera. A sharp focus will be the difference between registering faint meteors or missing them altogether in your images.



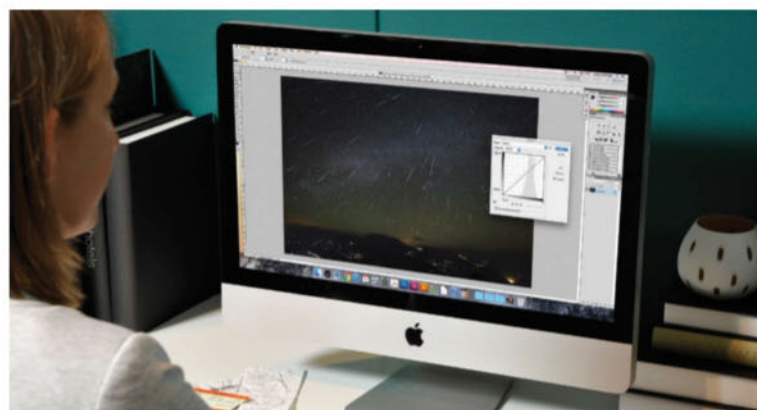
4 Set up the intervalometer

Set up your programmable shutter release for exposure lengths of around 20-25 seconds and for continuous shooting. This will control the camera.



5 Check the memory card

Keep an eye on the camera's memory card. It can fill up quite quickly when shooting in RAW, so make sure you have a spare to hand for when it's full.



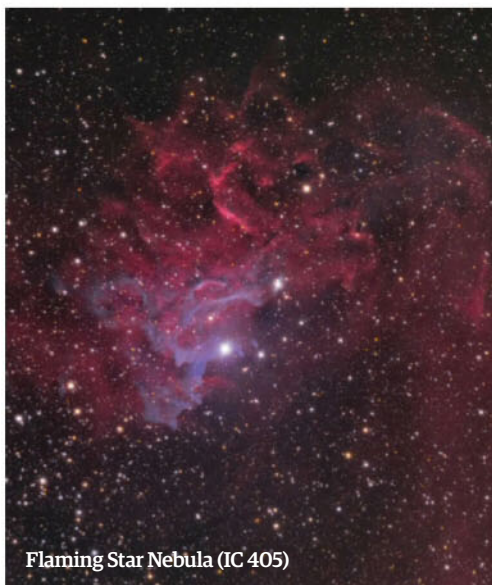
6 Process the shots

Go through the frames you have taken, ensuring that you save the ones with the most meteors. Use photo-editing software to adjust the contrast.



Crab Nebula (M1)

Deep sky challenge



Flaming Star Nebula (IC 405)

The Bull and Charioteer's deep-sky wonders

In the late autumn, the constellations of Taurus and Auriga are packed with objects for telescope owners

The constellations of Taurus and Auriga are a rich hunting ground, full of star clusters and nebulae to delight the telescope user. Quite apart from the famous open star cluster of the Pleiades, which is great to explore with a telescope of any size, there are other clusters that are equally rewarding. There are nebulae, too, perhaps the most famous of these being the Crab Nebula (M1), which was the first object on Charles Messier's well-known list.

Head into the constellation of Auriga, which is attached to Taurus by the star Elnath, also known as Beta Tauri, and you'll find a chain of impressive star clusters and another nebula known as the Flaming Star Nebula (IC 405), which is harder to see visually - the star is embedded in the nebulosity.

This is a fascinating region of the sky and well worth exploring with a telescope. Here are a selection of objects for you to observe with your telescope.

1 Hind's Variable Nebula (NGC 1555)
NGC 1555 is an intriguing object, which varies in brightness, as does the star that illuminates it.

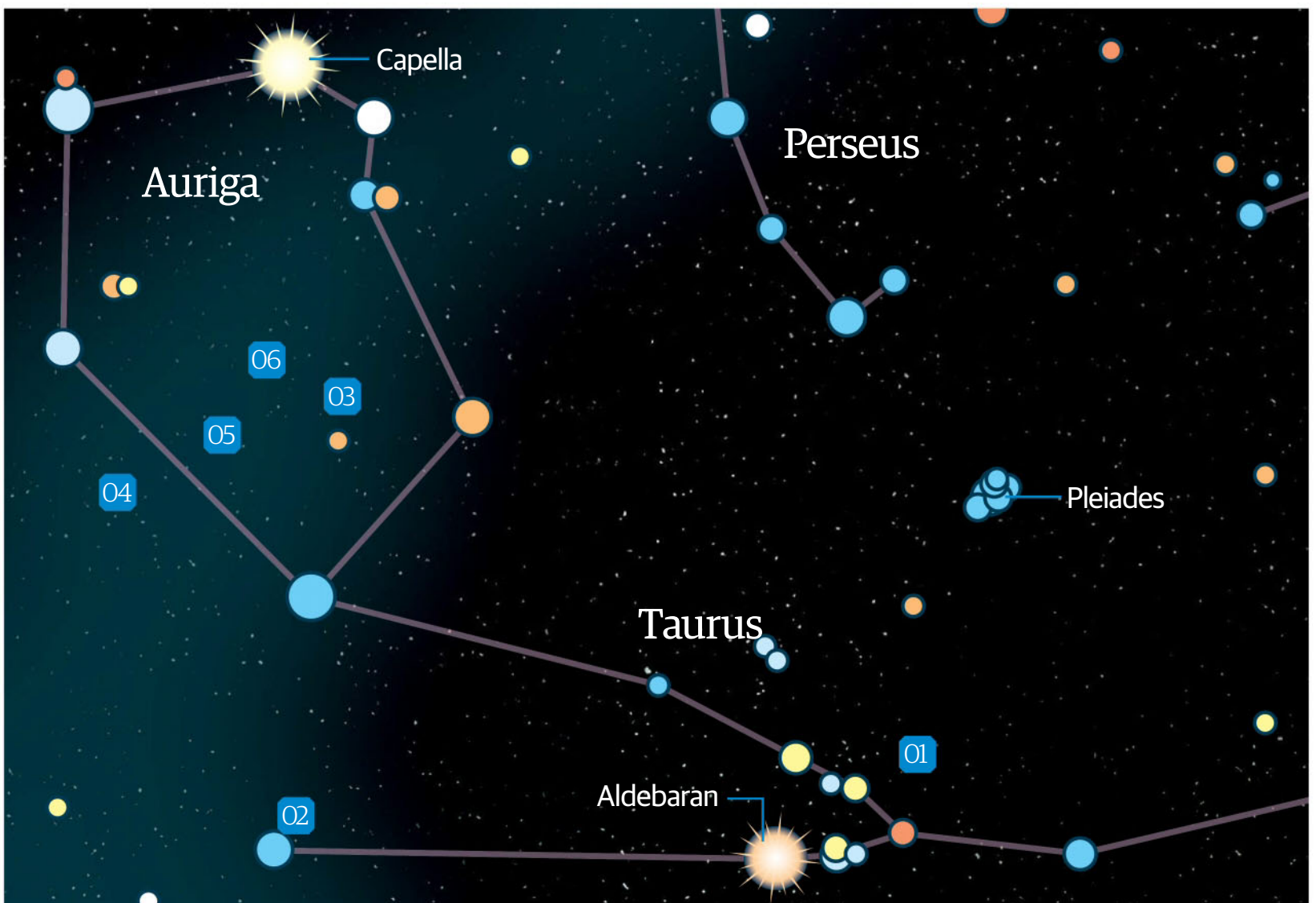
2 Crab Nebula (M1)
This is a supernova remnant - the matter left over after a star explodes. The stellar eruption was initially recorded in 1054 by the Chinese.

3 Flaming Star Nebula (IC 405)
Containing both an emission and a reflection nebula, this object covers an area of sky about the size of the full Moon.

4 Open star cluster M37
The brightest of the three star clusters in the constellation of Auriga, M37 can be resolved at medium power in a small telescope.

5 Open star cluster M36
Although not as impressive as M37, a small telescope at low power will reveal the member stars of this deep-sky object.

6 Open star cluster M38
The faintest of the three clusters in this region, M38 is also known as the Starfish Cluster.





How to...

Shoot the Pleiades star cluster

Now on display in Taurus, this deep-sky object provides the perfect opportunity to try your hand at wide-angle shots

You'll need:

- ✓ Small telescope
- ✓ Equatorial tracking mount
- ✓ DSLR camera
- ✓ Infrared or remote shutter release

Most people are familiar with the Pleiades star cluster. Its seven bright stars in a small group are instantly recognisable on a winter's evening. But there are, in fact, many more than seven stars in the cluster. It is now thought that there may be over 1,000 stars associated with the group. Less well known is that there is also a nebula associated with the Pleiades. This is a faint reflection nebula that is difficult to see visually, but it shows up well in long-exposure astrophotographs.

It was once thought that this nebulosity was the dust left over after the star formation, but it has now been realised that the cluster is just passing through a particularly dusty patch of the interstellar medium. The dust is reflecting the light of the glowing stars and it also happens to make

this group particularly photogenic. In order to be able to capture this nebulosity with the bright stars, you'll need a DSLR camera with removable and interchangeable lenses. This is important, as you'll need to either attach a telephoto lens of 500mm focal length or more, or be able to attach it to a small telescope in order to achieve the best results.

Remember that the cluster is quite large and this means that you don't need a lot of magnification – a small, short focal length telescope will work best. Achieving a good focus is important here too. You can check this by using your view screen and zooming in on the image and adjusting your telescope's focuser to get the image as sharp as possible. The same applies if you are using a telephoto lens. It is best to take a series

of shorter exposed images and stack them together in software, rather than take just one long exposure. This will help reduce the effects of mistracking of your mount and any atmospheric turbulence. A remote control shutter release is also really useful, as this will minimise the vibrations that can be introduced when pressing the shutter button by hand.

Depending on the settings of your camera and/or telescope, you'll need to vary the exposure lengths. It is good to take a few short exposures, as well as a few longer ones, to see which gives the best results. They can all be combined into the final image. Set the ISO value between 400 and 1600, although it is worth experimenting with this. Process the images with RegiStax or DeepSkyStacker, which are both free to download on the internet.

Tips & tricks

Use a small telescope

A small, short focal length refractor scope will give the best results.

Employ a tracking mount

An equatorial mount with good polar alignment will keep the cluster in the field of view.

A DSLR camera is ideal

A DSLR camera will allow you to attach it to a telescope or use a telephoto lens.

Use a telephoto lens

A camera lens of at least 500mm focal length is ideal for this tutorial.

Download free software

Process the images you take in either RegiStax or DeepSkyStacker, which are free to download online.



Improving your shots of the Pleiades

How to get really good image results that you can be proud of

Good focus is really important with deep-sky images and it's worth spending time on this. It's also good to take a number of images of varying exposure lengths. You probably won't need to use exposures of more than a couple of minutes, but if you can, give

it a try. The more images you take, the more likely you are to get good results. Follow the instructions for processing these images in free software such as RegiStax or DeepSkyStacker and give them a final tweak in Photoshop, which you'll need to buy.

Send your photos to
photos@spaceanswers.com



1 Set up your camera

Either attach your DSLR camera to a small telescope, or attach a telephoto lens to your DSLR camera, depending on what equipment you have.



2 Align the equatorial mount

Make sure your tracking mount is well polar-aligned and that the drive is switched on. This will ensure steady images.



3 Adjust the focus

Point the telescope at the Pleiades star cluster and take your time in getting a good focus. A sharp focus is important for taking deep-sky images.



4 Set the ISO

Set the camera's ISO to between 400 and 1600. Experiment with these settings and check a couple of images to see what works best.



5 Adjust the exposure time

Take lots of shots with varying exposure times. Again, check a couple of the images to see which exposure length is working best.



6 Develop your shots

Process the images that you've taken in free software such as RegiStax or DeepSkyStacker. Make sure you share your results on social media!



The Northern Hemisphere

The constellations of winter offer a much wider observing range for the naked eye, binoculars and telescopes

Along with the planetary members of our Solar System making their way along the ecliptic, a gaggle of deep-sky objects are there for astronomers to enjoy during mid-November and through to early December evenings.

The constellations of winter have started to make themselves known. Orion, Cetus, Canis Major and Taurus make a dramatic entrance in the darker skies, appearing to push the autumn star

patterns out of view, but still providing the perfect chance to observe a selection of targets across two seasons.

In particular, the Andromeda Galaxy (M31) and its satellites are still easy 'prey' for those with telescopes with at least a small aperture, while the Orion Nebula (M42) is easy to spot with the naked eye from a dark sky site, or with binoculars and telescopes in light-polluted skies.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

EAST

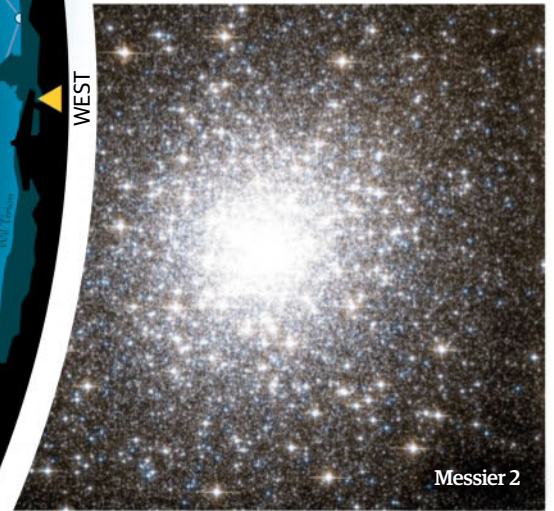
SE

Observer's note:

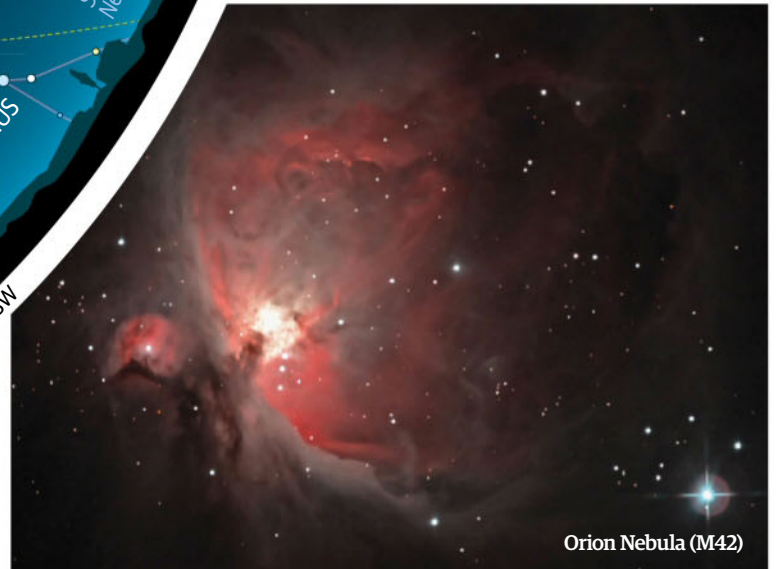
The night sky as it appears on 16 November at approximately 10pm (GMT).



Pinwheel Galaxy (M101)



Messier 2



Orion Nebula (M42)

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STARGAZER

Me & My Telescope

Send your astrophotography images to photos@spaceanswers.com for a chance to see them featured in **All About Space**

Paul Swift



Valencia, Spain

Telescope:

Vixen VSD 100 f/3.8

"I have a background in the arts and worked professionally as a cinematographer and

lighting cameraman - astrophotography made for a natural change in focus. I have always wanted to turn my camera to the night skies and moving from London to the less light-polluted city of Valencia, Spain, presented me with the perfect opportunity to do just that. The combination of exploring deep space and the creative and technical art form that is astrophotography has offered a powerful and alluring vocation. On any clear night, I can be found setting up under darkening skies for a night of astrophotography."

Nebulosity around Gamma Cygni

Jellyfish Nebula

Supernova remnant G82.2+5.3



Composite of a lunar eclipse



Solar prominence in H-Alpha

STARGAZER Me & My Telescope



Roger Hutchinson



Wimbledon, London

Telescope: Lunt LS60 solar telescope
& Celestron EdgeHD 11"

"I first became interested in astronomy and space as a child in the 1970s, right at the end of the Apollo programme. My dad helped me build an 8" Dobsonian telescope, through which I caught my first sight of Saturn and the craters of the Moon. I was hooked from that point! I started imaging with an old film SLR camera but the results were never what I had hoped for, so I parked my hobby until digital photography came along. For the past five or six years, I've been pursuing astrophotography over observational astronomy - my favourite targets are still the planets and the lunar surface."

Alan Dyer



Alberta, Canada

Telescope: Borg 77mm ED II
f/4 Astrograph

"Rural Alberta presents fine opportunities for photographing the night sky. I love heading south as often as I can to sites below

the equator to take in the wonders of the Southern Hemisphere. Only from 'down under' can you get the best views of the Magellanic Clouds and southern Milky Way sights such as the Carina Nebula. To capture the southern spectacles, I spent two weeks under mostly clear skies near Coonabarabran, New South Wales, billed as the 'astronomy capital' of Australia. Most nights were perfect for observing - clear, dry, mild, and with no wind, bugs or dew, it was heaven on Earth for stargazing."

Milky Way Galaxy



Great Carina Nebula



Centre of the Milky Way Galaxy

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Meade Adventure Scope

An entry-level spotting scope with an unusual design, this brand new series from Meade Instruments is ideal for viewing night-sky objects and wildlife

Telescope advice

Cost: £99.99

From: Hama UK Ltd

Type: Spotting scope

Aperture: 80mm

Best for...



Intermediate



Medium budget



Terrestrial observing



Planetary viewing



Lunar viewing



Digiscoping

A new range of spotting scope from Meade Instruments Ltd, the Adventure Scope series, supplied with apertures of 60mm and 80mm, is ideal for those who are keen to observe nature and want to break into astronomy - we recommend the spotter with the larger objective lens for optimum light-collecting ability.

As with all telescopes, spotters and binoculars manufactured by Meade Instruments, a generous number of accessories are supplied with the Adventure Scope and its tripod - a backpack for comfortable portability, two 1.25-inch Huygens eyepieces (H18mm and H6mm), a 1.25-inch 90-degree star diagonal and a red dot viewfinder are included, putting the Adventure Scope ahead of other spotting scopes on the market.

On first impressions, the Adventure Scope doesn't look like your standard spotting scope; it mixes the qualities of a telescope without compromising on a lightweight design for observers on the go. Its beige paintwork is unusual but makes it instantly recognisable and suitable for those wanting to go undetected when viewing easily-startled birds and deer.

The overall design is exquisite, showing off a well-made and robust build that's prevalent in other Meade instruments. The tripod, which is shorter than those supplied with telescopes, is sadly quite flimsy - something that has suffered in the making of a portable instrument that can be packed away in the supplied backpack. Those who wear spectacles won't get a great deal of eye relief from the eyepieces, which would have benefitted from eyecups for comfortable viewing. However, given the 1.25-inch eyepiece barrels, the Adventure Scope allows observers to accessorise without any difficulties.

Unlike many spotting scopes on the market, the Adventure Scope series doesn't come with a zoom eyepiece or a special waterproof design, which is boasted by the Meade Wilderness series. However, given that standard

"The overall design of the Adventure Scope is exquisite, showing off a well-made and robust build that's prevalent in Meade instruments"

Two 1.25" Huygens eyepieces (H18mm and H6mm) are supplied among other accessories. However, we recommend swapping these for eyepieces with eyecups for improved eye relief



The beige paintwork is pristine, while the build of the tube is excellent, boasting a superior setup compared to other spotting scopes on the market



telescopes survive the condensation that a change in temperature can bring - especially when moving an instrument from the warm indoors to the much colder outdoors - we didn't feel that this was a massive negative point. We do advise though, that you pay close attention to the condition of the objective lens' coating and optical system in general, to ensure that the instrument is performing at its best.

With the long, darker autumn evenings upon us, there were plenty of night-sky objects to test the Adventure Scope's mettle, with a variety of planets, nebulae and star clusters within easy range of its 80mm objective lens. With the Sun below the horizon by 6pm and a dark sky by 7pm (BST, 22 October 2016), we observed a selection of autumn targets before a third quarter Moon rose to wash them out. With no houses or trees to spoil the horizon, we took advantage of Mars' position, low in the west shining at magnitude -0.2.

Mars was easy to locate with the help of the red dot finder, which made star-hopping a breeze. Views of the Red Planet were small in the field of view, as what appeared as a reddish-orange star to the naked eye was resolved into a salmon-pink disc. We couldn't see any detail on Mars'

surface but views were crisp and clear.

Smoothly slewing to Mizar in the constellation of Ursa Major, we were able to split the star system into two components, with the fainter but still notable Alcor easily visible through the 80mm aperture. Meanwhile, close-up views of the Pleiades star cluster (M45) were spectacular as its member stars were pin-sharp in the field of view.

As the evening wore on, a third quarter Moon made its appearance and we took advantage of the terminator. Craters beautifully fell into light and shadow, providing views that would delight keen lunar observers. There was a degree of colour fringing when viewing bright objects but this didn't impair the views.

For astronomical viewing, the Adventure Scope is ideal for brighter night-sky targets but can also be used for comfortable views of the more diffuse, fainter nebulae. If you are an astronomer who likes to travel, this spotter is worth considering. But if you like nothing more than watching nature at play and dabbling in astronomy, then this spotting scope is a must-have - especially if you're keen to accessorise your instrument.



The tripod is short and, for comfortable viewing, will need to be placed on an elevated platform

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MEADE INSTRUMENTS

Meade LightBridge Mini 114

The LightBridge Mini is the ultimate grab-and-go telescope, providing the same high-quality standards of the original Truss-Tube Dobsonian models but in a portable form. The Meade LightBridge Mini 114 offers magnificent views of planets, nebulae, star clusters and galaxies thanks to its excellent light gathering ability. Its simple point-and-look design and a 360-degree 'Lazy Susan' style mount make it the perfect telescope for the entire family.

Meade Wilderness 20-60x80 Spotting Scope

Featuring high index Bak-4 prisms, as well as high-quality, precision lenses finished with layers of anti-reflection coatings for optimal performance, the Meade Wilderness is ideal for those who enjoy nothing more than dabbling in everything from bird-watching to observing the night sky. Magnifications from 20x to 60x, combined with an 80mm objective, provide bright and detailed images for a superb viewing experience, while a sliding sunshade reduces glare and rugged, rubber armour provides an exquisite finish for a waterproof and fog-proof design.

To be in with a chance of winning, all you have to do is answer this question:

What are the names of Mars' moons?

A: Europa and Io

B: Phobos and Deimos

C: Dione and Enceladus

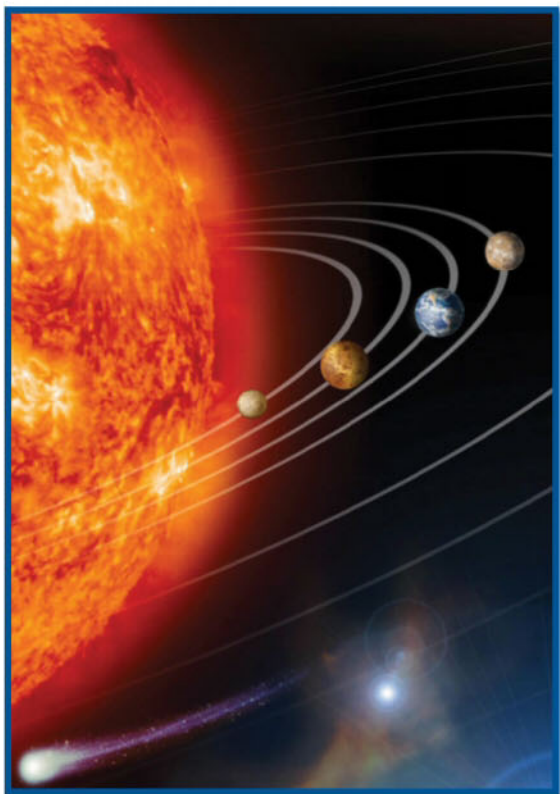
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Meade ETX90 Observer

Get stuck into astronomy with the ETX90 Observer. This automated and portable telescope provides exquisite views of a menagerie of night-sky objects - from the Solar System to galaxies and nebulae - thanks to its Maksutov-Cassegrain optical design with extraordinary contrast. The ETX90 Observer features AudioStar, GoTo technology and a large 30,000-object database, which will make finding your way around the night sky fun and educational for all.



Planet Earth Education



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- **Constellations can be used for navigation.**
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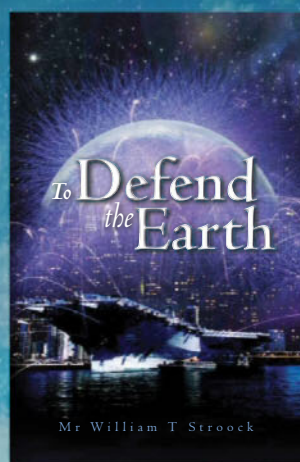
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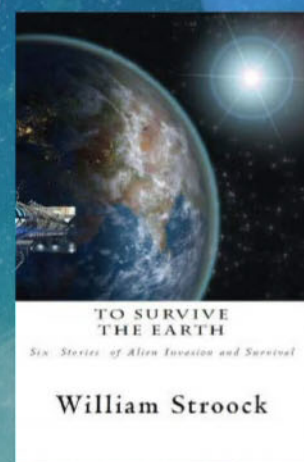


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TWO NOVELS OF ALIEN INVASION AND WAR



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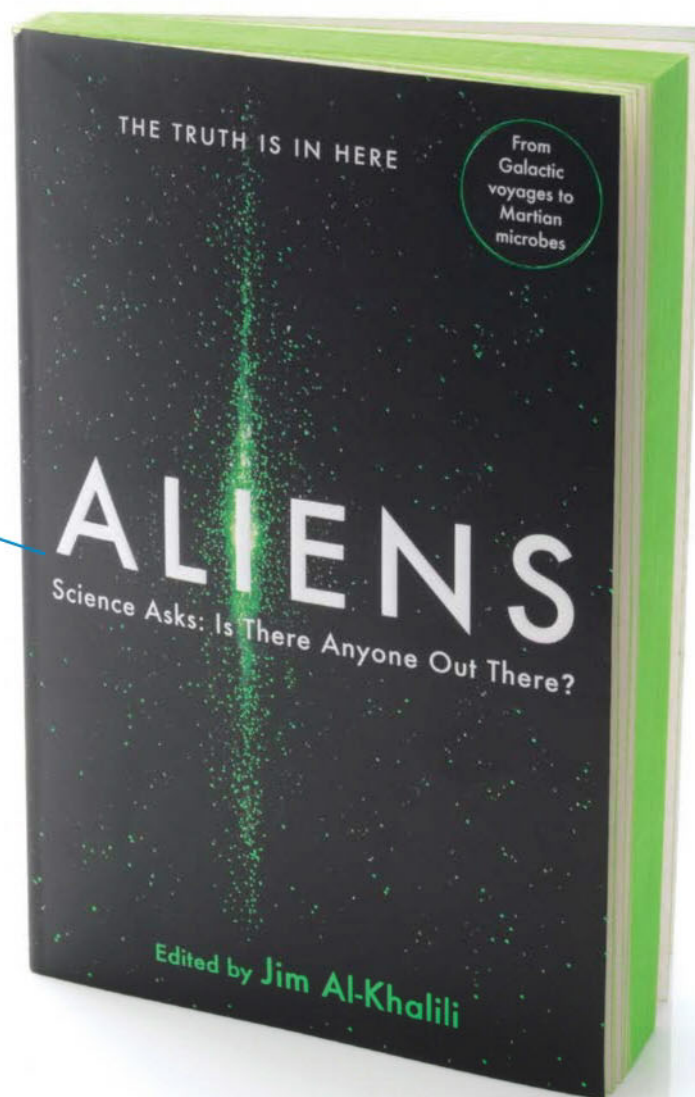
Aliens: Science Asks: Is There Anyone Out There?

Cost: £8.99 (approx. \$11.00)

From: Profile Books Ltd

It addresses one of the biggest questions: are we alone in the universe? Edited by professor of theoretical physics, broadcaster and author, Jim Al-Khalili, *Aliens: Science Asks: Is There Anyone Out There?* covers every aspect of our hunt for alien life, what other lifeforms may be like and how they could behave if we were ever to make contact. If you're keen to know more about the Search for Extraterrestrial Intelligence and want to get up to speed on the latest research, then this is certainly worth a read.

Split into 20 chapters and written by experts at the forefront of research - including Martin Rees, Adam Rutherford and Ian Stewart - this book changes pace in such a way that we were unable to put it down. It provides an even-handed, honest and balanced view of what we really know about other lifeforms on other worlds, and while it may be considered to be a bold move, we enjoyed the neuroscience behind alien abductions. Combined, the prose and subject matter is engaging and digestible, and it seemed that we'd finished this book as soon as we'd started it, which is the mark of an excellent work.



Software

Universe Sandbox²

Cost: £18.99 / \$24.99

From: Steam Play

A space simulator that can be downloaded to your computer, Universe Sandbox² is ideal for those who are keen to mix their love of gaming and the cosmos. Unlike many games on the market, however,

Universe Sandbox² doesn't have a mission, but you can have fun creating universes, playing with existing ones and the objects within them. On the whole, the developers have impressively ensured that all the components within this virtual cosmos - including planets, comets and stars - act as they should when obeying the laws of physics. If the user alters the systems in anyway, chaos unfolds, revealing how the Solar System and our galaxy could be affected if the balance of the universe is upset even slightly. In general, the premise of the game is simple: put various rocks in space, set various physical properties including velocity, mass and density, then watch them get to work. Whatever you decide to do - whether it's making the Earth the same size as the Sun, throwing Mercury past the orbits of Uranus and Neptune, or accidentally blowing up Jupiter and watching it form a second asteroid belt - Universe Sandbox² is certainly worth having a play with, given its modest price tag.



App **Luminos Version 9.1**

Cost: £14.99 / \$19.99

From: iTunes

Luminos has all of the workings of an excellent astronomy app and allows observers of the night sky to simply point and scan the heaven. It provides a fast and easy way of identifying a wide range of planets, stars, galaxies and nebulae, without having to consult the internet or an observer's guide. We are particularly enamoured with Luminos, given that it offers that touch extra over other apps, including the ability to mark objects as you find them while touring the stars, as well as record dates and add notes.

Luminos contains a large catalogue of objects, making users feel that they are getting a complete guide to what there is to know about observing the universe. If you're keen to watch satellites make their way across Earth's sky, then you'll enjoy Luminos' 'Hitch a ride on a satellite' feature, which allows you to gain a bird's-eye view of countries from space. There is also a function that allows you to choose to observe from another world in the Solar System, or set a similar field of view to your telescope or binoculars, assisting with star-hopping and helping you find objects with minimum fuss. Luminos, launched in 2010, is easy to download and doesn't seem to experience any freezing or crashing. Navigation is smooth and works very closely to 'real-time' with no lagging.



Binoculars

Olivon PC3 8x56

Cost: £329.99 (approx. \$400)

From: Optical Hardware Ltd

If you like to dabble in a bit of everything and are looking to add astronomy to your list, then the Olivon PC3 8x56 binoculars are perfect if your budget isn't too tight.

Lightweight with a compact open-bridge design, they are ideal for carrying around during a busy day outdoors and can be hand-held for a long time while scanning the heavens. What's more, these 8x56s are ideal for any weather; they are nitrogen-filled, making them waterproof and fog-resistant. While cheaper binoculars exist on the market, the Olivon PC3 series are of very good build quality.

Twist eyecups are made for superior use, while tethered eyecups ensure that you don't lose them - something many owners have grumbled about - and a ten-year guarantee also provides a safety net. Putting them to the test, the Olivon PC3s are comfortable to hold and use. Given their magnification, they are better suited for lunar observations and general views of planets, naked eye star clusters and nebulae, as well as terrestrial use.

They are ideal for those with a casual interest in astronomy and complement other outdoor activities.





Sir Roger Penrose has written a number of best-selling science books including *The Road To Reality*

Roger Penrose

His academic work has changed and shaped the way we currently see space

Scientific theory has taken many twists and turns over the decades, with fresh discoveries casting new light on old ideas and deep thinking leading to startling conclusions. Theorist Roger Penrose has never been shy when discussing hypotheses that go against the current belief systems and his contributions to physics and mathematics have earned him the greatest of respect.

Penrose was born on 8 August 1931 in Colchester, England. His mother was a doctor and his father was the pioneering psychiatrist and medical geneticist, Lionel Penrose. He graduated with a first class degree in mathematics from University College London, and completed his PhD at St John's College, Cambridge in 1957. But it was his work in the 1960s that brought him to prominence.

In 1965, his paper *Gravitational Collapse And Space-Time Singularities* proved groundbreaking, establishing the existence of cosmological singularities in the framework of general relativity. It showed how continual gravitational collapse under the existence of a trapped surface gave rise to space-time singularity, and the work proved vital in showing how Albert Einstein's general theory

of relativity implied space and time had a beginning in the Big Bang.

Penrose also worked in collaboration with Stephen Hawking on gravitational singularity theorems in relation to the cosmological Big Bang and he developed ideas about black holes. His papers showed that mathematical singularities were an inevitable initial condition that could be explained by general relativity and that black holes were like a reverse Big Bang. It was revolutionary.

Even so, Penrose also had other ideas up his sleeve. He developed twistor theory with his associates, lending mathematical insight into theories that lay deep within the standard model of particle physics, as he sought to unite relativity and quantum theory. In this, the relation between events in space-time is said to be vitally important, described using the geometry of twistor space. Penrose's 1967 paper has subsequently led to a proposed connection between string theory and twistor geometry.

It is no surprise, then, that Penrose's work has earned him a good number of prizes and awards. He was elected a Fellow of the Royal Society of London in 1972 and a

Foreign Associate of the US National Academy of Sciences in 1998. His contribution to our understanding of the universe was also recognised by his country when he was knighted for his services to science in 1994.

Yet he remains curious, constantly trying to address questions of potential higher dimensions of space and time and the origins of the universe itself. Indeed, in 2010 Penrose claimed to have glimpsed the universe before the Big Bang, having studied data collected by NASA's WMAP satellite. This supported Penrose's idea of conformal cyclic cosmology - the Big Bang was one of a series of cyclical big bangs.

Essentially, this means that he believes our universe was not the first to have been born out of a highly ordered, dense mass. The problem with the Big Bang model, he has argued, is that there is no explanation for why such a low entropy state existed in the first place. Although his idea flies in the face of inflationary theory, he posits that the universe will return to that state once more and that it most likely already has.

Today, aged 85, Penrose works on developing theories and pushing the frontiers of science in his role as the Emeritus Rouse Ball Professor of Mathematics at the Mathematical Institute of the University of Oxford, UK. His work continues to be lauded and he's even been depicted in film: in 2004 BBC drama *Hawking* and in the 2014 film *The Theory Of Everything*. He is a true star of science.

All About Space

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Shutterstock; Alamy; Tobias Roetsch; NASA; ESA; JHUAPL; Michelle Andonian, The Henry Ford

Photography

A. Block; A. Feld; Alamy; A. Loll; Ames; A. Riess; ASU; Ball Aerospace; CERN; CloudsAO; CNRS; CXG; D. Clowe; D. Magee; DPAC; Ed Crookes; ESA; ESO; F. Ferraro; Freepik; Gaia; Getty images; G. Illingworth; Harris Corporation; H. Ford; Hubble; the HUDF Team; J. Dai; J. Hester; JHUAPL; J. Lotz; J. Nichols; JPL-Caltech; K. Franklin; K. Hansen; K. Noll; L. Calçada; L. Jenkins; L. Sromovsky; M. Andonian; M. J. Jee; Magellan; Mount Lemmon SkyCenter; MSSS; NASA; N. Risinger; Neo Phoenix; P. Oesch; P. Souza; R. Bouwens; R. Sinyak; S. Beckwith; S. Smartt; SEArch; Shutterstock; SpaceX; SSI; Stanford University; STScI; SwRI; Thinkstock; TJT Photography; Tobias Roetsch; University of Arizona; University of Texas; USGS; Warner Brothers; Wil Tirion; W.W. Keck Observatory; Yale

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Printing & Distribution

Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed in the UK, Eire & the Rest of the World by

Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
☎ 0203 787 9060 www.marketforce.co.uk

Distributed in Australia by Gordon & Gotch Australia Pty Ltd,

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ISSN 2050-0548



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